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ANALYSIS
OF A
Courſe of Lectures
ON
NATURAL and EXPERIMENTAL
PHILOSOPHY.

VIZ.

ASTRONOMY,
Uſe of the GLOBES,
PNEUMATICS,
ELECTRICITY,
MAGNETISM,
CHYMISTRY,
MECHANICS,
HYDROSTATICS,
HYDRAULICS,
ENGINEERING,
FORTIFICATION,
OPTICS, &c.

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Teacher of the Belles Lettres *in MANCHESTER.*

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Advertiſement.

AS many who attend this courſe may not have made philoſophy a previous ſtudy, *it may be ſuppoſed that many of its uſeful parts will eſcape the memory; 'tis therefore at the requeſt of* thoſe *I have drawn up this Analyſis; by a ſhort look at which any particular propoſition or experiment will recur to the memory, and relieve the mind from thoſe errors which always attend indiſtinct ideas.*

ANALYSIS

OF A

Courſe of Lectures

ON

Natural and Experimental PHILOSOPHY.

15·12·02

LECTURE I.

ASTRONOMY.

AN hundred and fifty years are ſcarce elapſed ſince the clouds of prejudice which had long overſpread the world began to clear up, and men were convinced by cultivating the ſciences, and attending to nature, that no *fanciful conjectures* could ever lead them to the true cauſes of thoſe various phenomena that inceſſantly and every where meet the obſerver's eye; but that the narrow limits of the human underſtanding, confine the courſe of our reſearches to *one ſingle path*, namely that of *experiment*, or the *uſe of our ſenſes*. Yet in this ſhort period, natural philoſophy hath riſen to an high pitch of improvement, and may with truth be ſaid, to have made much greater advances towards perfection ſince the experimental method was introduced, than in the many ages before.

BECAUSE many bodies are reducible to water, *this* element has been thought by many able philoſophers to be the primary origine of all matter; and that bodies differ only as they contain more or leſs *particles*, or *pores* differently diſpoſed. But we ſhall find the decompoſition of bodies finite, being unable to carry it beyond a certain limit; if we attempt to go further, we are always ſtopt by ſubſtances in which we can produce *no change*, which are incapable of being reſolved into others, and which ſtand as ſo many *firm barriers* obſtructing our progreſs. To theſe ſubſtances we affix therefore the name of principles or firſt elements, and they are *earth*, *air*, *fire*, and *water*.

THE particles of matter are, 1ſt. *Impenetrably hard*, proved by water falling in vacuo. 2d. *Infinitely ſmall and diviſible*, proved by a candle filling a ſphere of four miles in diameter in a ſecond of time; by odours; by beaten gold; by copper diſolved in aqua-fortis, *&c.* 3d. *Inert*, i. e. can neither move, or ſtop of itſelf, proved by a ball on the whirling table, which neither begins to move when the table moves, nor ſtops when the motion of the table is ſtopped. 4th. Endowed with the principle of *attracting*; and being *attracted*, 1ſt. By *coheſion*, by which ſolid bodies are formed; for gold, iron, wood, *&c.* could not ſtick together but for this principle: When particles are brought within the ſphere of one another's attraction they form bodies; proved by ſurfaces of lead, iron, and marble ſticking together; this principle proved *not* to be the preſſure of the air by an endeavour to part the plains in vacuo. 2d. By *attraction of gravitation*, which is as it were the attraction of each particle of the earth accumulated into one maſs, and reaches far beyond the orbit of the moon, and is the reaſon of weight, or that tendency which all bodies have towards the centre of the earth; this principle is proved by two cork balls attracting one another as ſwimming on Water; and by the deſcent of Bodies;

this power decreaſes as the ſquares of the diſtances increaſe, i. e. a ball 9*lb.* on the ſurface of the earth would but be 1*lb.* at three ſemidiameters of the earth above it, *&c.* proved by comparing how far a body falls near the ſurface in a ſecond of time, to what the moon falls from a tangent to her orbit in the ſame time.

The planets are retained in their orbits by this *power of gravity*,---but as the ſun is by far the largeſt body in our ſyſtem, if no other power acted on them they would be *drawn down to the ſun.* All bodies therefore that move in curves as the planets do round the ſun muſt be acted upon by *two principles*, and motion being *rectilineal*, we ſuppoſe the Almighty gave each planet this kind of impulſe at its creation, ſo that between one power *drawing to the center*, and another *acting perpendicular to it*, the planets are impell'd in circles round the ſun, as a pebble tied to a mill-ſtone, and thrown from the hand, would revolve round the mill-ſtone. An idea of this is given by a ball impell'd ſingly in a ſquare in two directions, one perpendicular to the other; when both act they give the diagonal of the ſquare, *&c.*

Our ſyſtem muſt be conceived as within the concave ſphere ſeeming to be formed by the *fixed ſtars*, and the *ſun* as near the center of it, an huge globe of fire near a million of miles in diameter, and 95 millions of miles from the earth, according to calculations made by the the tranſit of Venus in the year 1761---He turns round on his axis in 25 days and 8 hours, as may be ſeen by ſpots on his face; and was no doubt intended to give light, heat, and vegitation to the 6 primary and 10 ſecondary planets which revolve round him.

All theſe *planets* move round the ſun from *weſt*, *by ſouth to eaſt*, in orbits which are nearly circular, and almoſt in the ſame plane. The *comets* move in all manner of directions, in orbits which are very long ellipſes, much inclined to one another, and to the orbits of all the planets. The tails of comets are only thin vapours, for if they were flame no ſtar could be ſeen thro' them.

The time in which any planet goes round the ſun is *the length of its year*, and the time in which it turns round on its axis, is *the length of its day and night* taken together, as repreſented on the orrery.

The neareſt planet to the ſun is *Mercury*; he goes round him in 87 days 23 hours, is about 3000 Engliſh miles in diameter, and diſtant from the ſun 42 millions of miles; he moves in his orbit about 100 thouſand miles every hour; the length of his days and nights are unknown, being but 56 times the ſun's apparent diameter from him, he ſets and riſes too near the ſun for any obſervations to be made of his ſpots.

Venus goes round the ſun in 224 days 17 hours, her diameter is near 7900 miles, her diſtance from the ſun is 79 millions of miles, her hourly motion in her orbit is 69 thouſand miles, and ſhe turns round on her axis in 24 days 8 hours of our time. By her axis inclining 75 degrees from a perpendicular to her orbit ſhe has two ſummers and two winters at her equator.

Her orbit alſo deviates 3½ degrees from the plane of the ecliptic, ſo that ſhe has two nodes, or places where ſhe croſſes the ecliptic, one in the 14th. degree of Gemini, and the other in the 14th. of Sagittarius. If the earth happens to be in thoſe ſigns when *ſhe is*, then we ſee her tranſit over the ſun's face, a phenomenon which happened the 1ſt. of April 1761, and gave the aſtronomers the opportunity of calculating the ſun's paralax (*viz.* 7½ minutes) and of conſequence his diſtance, as well as that of the planets.

THE *earth* is the next planet in the order of the ſyſtem,---but is explained in the next lecture.

Mars, ſtill higher in the ſyſtem is 167 millions of miles diſtant from the ſun, moves at the rate of 47,000 miles an hour, goes round the ſun in 678 days, and turns round on his axis in 24 hours 40 minutes of our time, and is about $\frac{1}{5}$ as large as our earth, his *red appearance* is occaſioned by a groſs, thick atmoſphere with which he is ſurrounded, and which is ſuppoſed to ſupply his want of a moon.

Jupiter, the largeſt of the planets is 570 millions of miles diſtant from the ſun, and above 400 millions from our orbit; he moves round the ſun in about 12 years of our time, at the rate of 30,000 miles per hour; he is near 90,000 miles in diameter (i. e. near 1000 times as large as our earth) is accompanied by 4 moons, ſome bigger and ſome leſs than the earth, which revolve round him, as our moon does round us; and the faint ſubſtances on his face called his belts are ſuppoſed to be parts of his atmoſphere drawn into lines by his exceeding quick revolution on his axis, which is once in 9 hours 49 minutes.

Saturn, the ſecond in magnitude and the moſt diſtant of all the planets, is 949 millions of miles from the ſun. Near 70,000 miles in diameter,---moves at the rate of 18,000 miles per hour,---but is too remote for his ſpots to be ſeen. He is equipt with *five moons*, beſides *a broad luminous ring* which alſo reflects the ſun's light ſtrongly upon him. This planet is near 30 of our years in making his revolution round the ſun.

THESE calculations are the lateſt and moſt accurate that have been made, they are given in round numbers, to eaſe the memory; and are founded on *mathematical* as well as *occular* certainty.

By the ſame kind of calculation the neareſt fixed ſtar is found to be 400 millions of miles further from us than the ſun, tho' the whole diameter of the earth's orbit, *viz.* 190 millions of miles will ſcarce form a *paralax* or *angle* with it. Light diminiſhing as the ſquares of the diſtances, the ſun's rays therefore cannot enlighten the fixed ſtars; and a teleſcope which magnifies 200 times does not ſenſibly magnify them; 'tis therefore highly probable they are *ſuns* like ours, ſhine by their own unborrowed luſtre, were not intended for our ſervice, but to give light, heat *&c.* to ſyſtems of worlds of their own, formed for the ſame purpoſes as ours, tho' too remote for our eyes aſſiſted by the beſt glaſſes. We find the worlds of our ſyſtem covered with *continents*, *ſeas*, *hills*, *&c.* Who can doubt therefore but they are inhabited, as well as all the worlds of the other ſyſtems? How much too big is this idea for the human imagination! By teleſcopes thouſands of theſe ſuns have been found more than the naked eye can perceive--- was our glaſſes ſtill better we ſhould no doubt find more---'tis not improbable there may be ſtars ſo far diſtant that their light has not reached the earth ſince the creation.

Let us on the wings of imagination then launch into the immenſity of ſpace, and behold *ſyſtem* beyond *ſyſtem*, *above us*, *below us*, to the *eaſt*, the *weſt*, the *north* the *ſouth!* Let us go ſo far as to ſee our ſun but a *ſtar* among the reſt, and our ſyſtem itſelf as a point, and we ſhall but even then find ourſelves on the *confines of creation!* How inadequate then muſt be the utmoſt ſtretch of human faculties to a conception of that amazing *Deity* who made and governs the whole! Should not the narrow prejudices, the littleneſs of human pride ſoften into humility at this thought?

LECTURE

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LECTURE II.

Uſe of the GLOBES.

WHEN a ſhip approaches us at ſea, the firſt part of her we ſee is her *upper ſails*, after that we ſee her *lower ſails*, and then the *hull*---'tis evident ſhe moves on a round ſurface or we ſhould ſee the whole at a time. In ſailing from capes we loſe ſight of 'em firſt at the *bottom*, then the *middle*, and at laſt the *top* diſappears. Theſe effects are in all parts of the world. Several have ſailed round the earth. And all the bodies in the ſyſtem are round. Hence we conclude that *the earth is a globe* alſo.

The earth's roundneſs is no more affected by the largeſt mountains, than the roundneſs of a common globe is by a few grains of duſt thrown upon it, for they bear no greater proportion to its bulk. It is 7970 miles in diameter. Near 100 millions of miles from the ſun. Moves round him in 365 days 5 hours and 49 minutes, at the rate of 60,000 miles an hour; and turns round upon its axis every 24 hours from weſt to eaſt which makes all the heavenly bodies ſeem to turn round the contrary way, or from eaſt to weſt.

The particles of which the earth is compoſed would fly into confuſion if not held together in the form of a globe by the *power of gravitation*. 'Tis this power which gives *weight* to all bodies, or that tendency they have towards the center of the earth. Hence the general *top* of the earth becomes its whole ſurface, and the general *bottom* its center. The *Antipodes* are therefore as much on the top as we. But as the parts of the earth are looſe, the violent motion it has on its axis will in ſome degree overpower even the force of gravity and accumulate more matter round the *Equator*, becauſe the *centrifugal force* is greateſt there; hence the true figure of the earth is an *oblate ſpheroid*, or like an orange, 35 miles more in diameter at the equator than at the poles. This was proved by an actual menſuration, and explained by the whirling rings.

THIS oblate figure proves its *diurnal motion*, if it was at reſt it would be neceſſarily a perfect ſphere. We perceive not this motion becauſe the *air* in which we live partaking of the general gravitation is carried round along with the earth. When a ſhip turns round if we look out at the cabin windows, we believe ourſelves at reſt and the neighbouring country turning round us,---we are deceived in like manner in the motion of the earth.

WHERE there is no reflection from contiguous objects, a globe can but be *one half* enlightened by a luminous body; hence if a globe turns round, there muſt be a ſucceſſion of light and darkneſs, or day and night to its inhabitants.

HAD a globe no other motion, there could be no variety in its ſeaſons or length of days. As gravity decreaſes according to the ſquares of the diſtances, it follows that if one body move round another as its center of motion, the ſquare of its periodic Times will be as the cube of its diſtance from that body; this holds preciſely with regard to the planets and their moons.--- The planets ſometimes appear to *ſtand ſtill*, ſometimes to *go backwards*; this muſt always be the caſe where one body moves in the ſame plane, in a circle within that of another moving body. The eclipiſes of Jupiter's ſatellites appear later to us by 16 minutes at one time of our year than at another. 'Tis matter of obſervation that all the planets revolve round the ſun. From all which we are certain that the earth goes round the ſun, and not the ſun round the earth.

We know the path our earth deſcribes in the heavens, by obſerving *that* which the ſun ſeems to deſcribe in the oppoſite part of the heavens. We find one ſtar without any apparent motion, ſituated 23½ degrees from the axis of this orbit, and which is occaſioned by being oppoſite to one of the poles of our earth, and thence called the polar ſtar; hence we diſcover that ſublime contrivance the inclined axis of the earth, which keeping always *parallel to itſelf*, occaſions the different ſeaſons, and different lengths of day and night, diffuſing equally over the face of both hemiſpheres the bleſſings of the ſun.

The axis ſo diſpoſed will neceſſarily bring the northern and ſouthern parts of the earth alternately to the ſun, therefore when tis ſummer in the *north* 'twill be winter in the *ſouth* and vice verſa. So far on each ſide the equator as the ſun ſhines vertical is called the *torrid zone*, and it is bounded by two imaginary lines, *that* to the north is called the *tropic of cancer*, and *that* to the ſouth, the *tropic of capricorn*. When the ſun ſhines vertical over the firſt, he muſt ſhine 23½ degrees further than the north pole, and will not therefore ſet for many days together to the inhabitants of the *north frigid zone*,--- but it will be then total darkneſs (the ſame time) to thoſe of the *ſouthern frigid zone*; hence the poles *muſt* but have one day and one night in the year. Theſe two zones are bounded by lines alſo, the north called the *artic*, the ſouth the *antarctic* circle. The intermediate ſpaces between the torrid and frigid zones are called the *temperate zones*.

In the northern hemiſphere the *vernal equinox* (or equal day and night in the ſpring) is on the 20th. of March; and the *autumnal equinox* is on the 23d. of September: In the ſouthern hemiſphere the contrary. At the equinoxes the ſun ſhines over the equator; at the *ſolſtices* he is 23½ degrees from the equator.

THE *meridian* of any place, is a ſemicircle paſſing thro' it, cutting the equator at right angles and terminating in the poles. The earth's circumference is 360 degrees, each near 70 Engliſh miles,---and as the earth turns round its axis in 24 hours, each meridian revolves 15 degrees in an hour, for 24×15=360. Therefore every place to the *eaſtward* of another has its hours ſooner, if *weſtward* ſo much later.

THE *longitude* of any place is the number of degrees between its meridian, and the meridian of any place, from whence the longitude is reckoned and is deemed *eaſt* or *weſt* according as it is ſituated. The eclipſes of *Jupiter's ſatellites* afford a method of finding the longitude, thus, ſuppoſe an eclipſe of any *ſatellite* happens at London at 6 in the morning, and that it is ſeen at another place at 4 in the morning; the difference of time is two hours which anſwers to 30 degrees, conſequently the meridian of the place where the eclipſe was ſeen at 4 in the morning, is 30 degrees weſt of London. Theſe obſervations the motion of a ſhip hinders from being made at ſea; but as the altitude of the ſun can be taken by the ſeaman's quadrant, *it* anſwers the ſame end,---and hence may be perceived the extreme utility of Mr. *Harriſon*'s time-keeper.

THE *latitude* of a place is ſo many degrees as it is from the equator, if to the north tis ſaid to be in *north latitude*, if to the ſouth of the equator, in *ſouth latitude*, ---hence by the lines of latitude and longitude, the face of a globe is covered with *imaginary ſquares* by which the ſituation of every ſpot on the face of the earth is as exactly aſcertained as the parts of an eſtate are by its hedges and ditches.

THE *rational horizon* of a place extends 90 degrees from it on all ſides. The *ſenſible horizon* is the boundary of the obſerver's ſight.

THE *ecliptic* is that circle in the heavens thro' which the earth and planets make their revolutions round the ſun,---and it is diſtinguiſhed by conſpicuous fixed ſtars called ſigns or conſtellations ſuch as *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *&c.* The *zodiac* extends to 8 degrees on each ſide of the ecliptic, and with it round the heavens.

THE four continents of the earth are *Europe*, *Aſia*, *Africa*, and *America*. The oceans are the *Northern*, the *Atlantic*, the *Ethiopic*, the *Indian*, the *Pacific*, and the *Southern Oceans*. The unknown parts of the earth contain 160,566,276 ſquare miles; the inhabited parts 38,990,569 i. e. Europe 4,456,065; Aſia 10,768,823; Africa 9,654,807; America 14,110,874. In all 199,556,845; which is the number of ſquare miles on the whole ſurface of our globe.

WHEN a round ball has the different countries, kingdoms, towns, and rivers delineated upon it agreeable to their ſituations, it is a repreſentation of the earth. If an hollow ſpherical ball could have the fixed ſtars properly marked on its inſide, with the ſun, moon, and planets, it would be a repreſentation of the heavens to an eye placed in its center, but this being inconvenient the fixed ſtars are placed on an opake globe, and the ſun and planets repreſented by patches placed on the ecliptic, becauſe they are continually changing their places.

PROBLEMS performed by the late invented Globe Machine.[*]

PROBLEM. *To find the latitude and longitude of a given place.*

---

[*] The familiarity of this machine, and the ſimplicity of its conſtruction, makes a bare inſpection of the lecture and the practice of the few following problems almoſt a ſufficient education in the uſe of the globes. ⁂ Common globes are hung in the ſame way on eaſy terms by the author.

Solution. BRING the place to the meridian and you have the latitude. Look where the meridian cuts the equator and that's the longitude, eaſt or weſt of London.

N. B. When we ſpeak of bringing any place to the meridian, the figured ſide of it is meant,---and the firſt meridian is that of London.

PROB. *The latitude and longitude of a place given to find that place on the globe.*

Sol. FIND the longitude on the equator, bring it to the meridian, then run the finger up the meridian to the given latitude, and under it is the place.

PROB. *To find the difference of latitude or longitude of two places.*

Sol. BRING each to the meridian, and note the latitude, ſubtract one from the other if they are on the ſame ſide of the equator; if not, add them together. The difference of longitude is found on the equator in like manner.

PROB. *A place given to find all thoſe places that have the ſame latitude and longitude with it.*

Sol. BRING the place under the ſolar index, (i. e. the pointer fixed to the horizon) and all places under the meridian are in the ſame longitude,---turn the globe and all places under the index are in the ſame latitude.

PROB. *To find the antipodes of any place.*

Sol. BRING the place under the ſolar index; then look at the ſame latitude in the other hemiſphere under the meridian, and that is the place.

Prob. *To find the diſtance between two places.*

Sol. Lay the graduated edge of the quadrant of altitude over both places, count the degrees and multiply them by 70 and the anſwer is in Engliſh miles.

Prob. *The hour of the day at any place being given to find all places where it is then noon.*

Sol. Tie a thread to the pole, bring it over the place and under the brazen equator, bring the thread to the hour on the equator, then 'tis noon at all places under the meridian.

Prob. *Hour of the day at any place given, to find what o'clock it is then at any other place.*

Sol. Bring the thread over the given place as in the laſt,---fix the globe there,---then where the thread in coming over any given place cuts the hour, on the brazen equator is the time.

Prob. *To find the ſun's place in the ecliptic.*

Sol. Bring the ſolar index to the day of the month on the little ſcale,---then turn the globe, and where the index cuts the ecliptic is the ſun's place. Where it cuts the meridian is the ſun's declination, or diſtance from the equator; and the globe in that ſituation is alſo rectified for the ſun's place.

Prob. *Day given, to find all thoſe places over which the ſun will paſs vertically on that day.*

Sol. Bring the day on the little ſcale to the ſolar index, and thoſe places to which it points as the globe turns round, the ſun that day paſſes vertically over.

Prob. *Place given in the torrid zone, to find the two days of the year on which the ſun will be vertical there.*

Sol. BRING the place under the ſolar index,---then turn the little ſcale to the index and it points out the two days.

PROB. *To find the day when the ſun begins to ſhine without ſetting on any place in the frigid zones.*

Sol. TURN the pole ſo far from the horizon that when the globe turns round the given place ſhall but juſt touch the horizon, then turn the little ſcale to the index and it points out the day.

PROB. *To find when it begins to be total night at any place in the frigid zone.*

Sol. TURN the pole ſo far on the night ſide of the horizon that the given place will but juſt touch it, as the globe turns round,---the index then points out the day as in the laſt problem.

PROB. *To find the place over which the ſun is vertical at any hour of a given day.*

Sol. RECTIFY the globe for the day by the ſcale and index, bring the meridian of London, or the place where you are to the given hour, then does the ſolar index point to the place required.

PROB. *To find when twilight begins or ends at any place.*

Sol. As twilight (by the refraction of the ſun's rays as will be explained in the lecture upon optics) reaches 18 degrees below the horizon, 'tis only meaſuring that diſtance with the quadrant of altitude, below the horizon, and the thread fixed to the pole, laid over that place and the equator, points out the hour.

PROB. *The day and hour at any place being given to find all thoſe places where the ſun is riſing or ſetting, on the meridian, and where 'tis midnight, &c.*

Sol. **Rectify** the globe for the day, and turn the given place to the hour, then to all places under the weſtern horizon or to your left hand as you ſtand before the globe, the ſun is riſing, to all places on your right or under the weſtern horizon he is ſetting, to all places under the day part of the meridian it is noon, and to all places under the night part of the meridian it is midnight.

Prob. *Time given, to find the length of the days and nights of any place on the face of the earth.*

Sol. **Rectify** the globe for the day, bring any place to the weſtern ſide of the horizon, and bring the thread over it and the equator, there it cuts the hour when the ſun riſes; repeat the ſame on the eaſtern ſide and you find when the ſun ſets,---the hours between the riſing and ſetting is the length required, and that ſubtracted from 24 is the length of the night.

N. B. The uſe of the celeſtial globe, being in every ones hand, I omit it here.

LECTURE III.

On the MOON, &c.

THE *moon* is no planet, but only a ſatellite, or an attendant on the earth. The farther any planet is from the ſun the more occaſion it has for ſuch an help to its light; hence Mercury and Venus are without moons, as being near the ſun, but Jupiter has four, and Saturn five, becauſe of their diſtance from it.

The moon's face abounds with greater *inequalities* than the earth, but hence ſhe reflects a more chaſte and

agreeable

agreeable light than if her ſurface was ſmooth. She always keeps the *ſame face* towards us (ſome ſay becauſe the quality of that ſide of her is more adapted to catch the attraction of the earth than the other) and conſequently muſt turn once round on her axis, while ſhe goes once round the earth in her orbit. Her ***periodical revolution***, or time of going round from one point of her orbit to the ſame point again is 27 days 7 hours 43 minutes: But her *ſynodical revolution* or time from change to change is 29 days 12 hours 44 minutes,---this difference is cauſed by what the earth has advanced in the ecliptic during that time, which is 29$\frac{1}{10}$ degrees. *(Proved by the orrery and Ferguſon's paradox.)*

The moon's diſtance, found by her paralax is 240,000 miles. Her diameter 2180 miles,---and ſhe moves about 2290 miles every hour.

The *moon* has no light of her own, but only reflects the beams of the ſun as a poliſhed body does the light of a candle,---hence as ſhe is a globe we muſt ſometimes ſee *more* ſometimes *leſs* of her enlightened ſide, *viz.* when ſhe is between us and the ſun, her dark ſide is towards us, and therefore ſhe diſappears; as ſhe advances forward we ſee a ſmall part of the enlightened ſide, and call it the *new moon*; before next evening ſhe is got a few degrees farther to the eaſt and we ſee *more* of her illumin'd ſide,---every evening we find her advanced till ſhe riſes in the eaſt in oppoſition to the ſun in the weſt, and then her whole enlightened face is towards us, and we ſay ſhe is at the *full*; her decline is from the ſame reaſons; and a ball over a gate enlightened by the ſun conveys a clear idea of both. *(Proved by the orrery).*

The earth is a *moon* to the moon, waxing and waning as ſhe does; it appears 13 times as large to the lunarians as the moon does to us, affording them both an uſeful and an amazing ſpectacle, for its continents and ſeas may be plainly perceived by them, as well as its rapid motion round its axis. *(Proved by the orrery.)*

THE planets as well as their ſatellites being *enlightened by the ſun*, muſt caſt *ſhadows* towards that part of the heavens oppoſite to the ſun. Was the earth bigger than the ſun its ſhadow would ſpread, and extend far beyond the orbit of mars, and conſequently *eclipſe him*, for he is but 42 millions of miles from the earth, but the earth's ſhadow never reaches him, therefore it muſt end in a *point* much ſhort of that diſtance; another proof how much the ſun is bigger than the earth! But the moon is eclipſed when ſhe falls into the earth's ſhadow, which for the reaſons above can never happen but when ſhe is at the *full*, becauſe that is the only time when ſhe is oppoſite to him, but was ſhe a *luminous body* ſhe could not be darkened by the earth's ſhadow. *(Proved by a real ſun and moon.)*

THE ſun is eclipſed when the moon paſſes directly between him and any part of the earth; this can only happen at the *change of the moon.* *(Proved in like manner.)*

WAS the moon's orbit in the *plane* of the earth's path round the ſun, ſhe would be eclipſed every time ſhe came to the *full*, and would eclipſe the ſun every time ſhe came to the *change*; but one half of her orbit is on the *north ſide*, of the ecliptic, and the other half on the *ſouth ſide* of it, and muſt therefore cut the ecliptic in two oppoſite points called the *moon's nodes.* The angle of this orbit with the ecliptic is $5\frac{1}{3}$ degres *(Shewn on the orrery.)*

WHEN the moon is at full above 12 degrees from either of theſe nodes, ſhe paſſes clear of the earth's ſhadow, and cannot be eclipſed; and when ſhe changes above 18 degrees from either of them, ſhe paſſes either above or below the ſun and therefore cannot eclipſe him: But if ſhe be at full or change within thoſe diſtances, then an eclipſe happens, and if ſhe be *in* the node the eclipſe is central. *(Explained by the paradox.)*

IF theſe nodes kept always in the *ſame* ſigns of the ecliptic, the ſun and moon would always be eclipſed in the ſame *places* and at the ſame *time* every year,---but the eclipſes *fall back* every year from the eaſt to the weſt, in ſuch a manner as to prove that the moon's orbit *moves backwards* 19⅓ degrees every year, ſo that in 18 years and 225 days there is a period or reſtitution of the ſame eclipſes; and they then appear in the ſame places and the ſame times as before. *(Proved by the paradox.)*

THE earth and moon are chained to one another as it were by their *mutual attraction*, which like the ſun and planets is in proportion to their quantity of matter. As the hand that gives motion to a ſling is drawn by it, ſo as to form an imaginary center of gravity, ſo is an heavy body by a lighter revolving round it. On this center of gravity the earth and moon revolve in *equilibrio*, and its diſtance from their centers is inverſely as their quantities of matter, *viz.* 6000 miles from the earth's; conſequently the center of gravity forms the *real orbit*, and makes the earth 12,000 miles nearer the ſun at the time of *full moon*, than at the time of its change. This is demonſtrable to the naked eye by the ſun's appearing ſo much larger at the full than at the change of the moon. *(Proved by the whirling tables.)*

THE farther any part of the earth is from this center of gravity, the greater is its tendency to fly of in a tangent,---therefore the *ſide of the earth* which is turned away from the moon has a greater *centrifugal force* than its *center* has: And this *center* a greater than *the ſide* next the moon. At the earth's *center*, the moon's attraction balances the centrifugal force, but muſt be *ſtronger* than the centrifugal force of the *ſide of the earth next her*, and *weaker* than the centrifugal force of the *ſide fartheſt from her*. As the moon's attraction is greater than the centrifugal force on that ſide of the earth next the moon, of courſe the *tide* will riſe on that ſide: But as the centrifugal force on the oppoſite ſide is greater than the moon's attraction, the tide will alſo riſe on that ſide; hence the reaſon of *two tides* in 25 hours. *(Proved by the tide table.)*

The ſun agitates the water in like manner very conſiderably, therefore when, the ſun and moon draw in the *ſame direction*, they cauſe a *ſpring tide*, and this happens at the change and full of the moon. But at the quarters when they attract in *contrary directions*, they deſtroy the effect of each other, and then we have *neap tides*. At the *equinoxes* the ſun and moon being both on or near the equator, their attraction is more in a *line* than at any other ſeaſon, hence the *prodigious tides* which generally follow theſe ſeaſons. A planet alſo falling in conjunction with the ſun and moon will encreaſe the tides ſtill more. *(Shewn by the tide tables.)*

The *air* being a fluid much lighter than water, is more affected by the moon's attraction; and we find that people diſordered in their ſenſes are much worſe when the ſpring tides are in the air, which tides are, as in the other element, at the full and change of the moon.

To the inhabitants ſituated at a conſiderable diſtance from the equator, the *different parts* of the ecliptic riſe at very *different angles* with the horizon. In northern latitudes, the ſigns *Piſces* and *Aries* riſe with the *ſmalleſt angles*; *Virgo* and *Libra* with the *greateſt*; therefore when the moon is in *Piſces* and *Aries* ſhe muſt riſe nearly at the *ſame hour* for ſix or ſeven days together. In *winter* the moon is in thoſe ſigns about the time of her firſt quarter, but as ſhe muſt then riſe about *noon*, *that* riſing is not taken notice of. In *ſpring* the moon is in them about her *change*, but as ſhe then gives *no light*, her riſing is alſo unnoticed. In *ſummer* ſhe riſes in *Piſces* and *Aries*, about her *third quarter* but at 12 o'clock at night, conſequently the phenomenon is ſeldom *then* regarded; but in *autumn* thoſe ſigns are oppoſite to the ſun, and therefore the moon muſt be *full* in them, and very uſefully for the farmers riſes in their harveſt immediately after ſun-ſet for ſeveral evenings together, and thence acquires the name of the *harveſt moon*. (*Proved by the orrery and globe.*)

LECTURE IV.

PNEUMATICS.

THE air is a thin fluid, which encompaſſes the globe of the earth on all ſides, it revolves along with it round its axis, and attends it on its annual journey round the ſun. If a peach be made to repreſent the earth the air will be aptly ſignified by the down growing on its ſurface.

THIS body of air, together with the clouds and vapours that float in it, are called the atmoſphere; and it reaches about forty five miles above the ground before it degenerates into too thin an ether for any creature to breathe; this is known by meaſuring with a barometer the weight of the atmoſphere in a low valley, and on an high mountain, and may be familiarized by ſuppoſing a thouſand fleeces of wool one piled upon another, where the loweſt will be greatly compreſſed or ſqueezed together, the next not ſo much, the next not ſo much as that, *&c.* till we come to the uppermoſt which will lie in its natural looſe ſtate. The air by partaking of the earth's attraction is neceſſarily drawn into a progreſſive ſtate like this.

THE air is ſo ſubtle that it pervades the pores of all bodies, and enters into the compoſition of moſt animal and vegitable ſubſtances; yet it is a body, becauſe it excludes all other bodies from the place it poſſeſſes, if ſo confined that it cannot eſcape; hence the origine of the diving bell, for if we ſink a bell in water with the mouth open downwards, little water will make its way into it, and a perſon may deſcend and live in the bell ſo long as to take up wrecks at a conſiderable depth, if a veſſel of the ſame kind be kept conſtantly ſupplying him with freſh air, and that corrupted by his breathing be let out by a pipe reaching from the upper part of the bell above the ſurface of the water.

THE air has all the properties by which a fluid is diſtinguiſhed, it yields to the ſlighteſt impreſſion, its parts move eaſily among one another, and animals breathe and move thro' it without any difficulty. Yet it has four ſingularities which diſtinguiſh it from moſt fluids. 1. It can be compreſſed into a leſs ſpace than it naturally poſſeſſes. 2. It cannot be congealed or frozen. 3. It is of a different denſity in every part upward. 4. It is of an elaſtic nature, and the force of its ſpring is equal to its weight.

As the air is a body it muſt needs have weight; this is proved 1. By its preſſing the hand that covers the top of an exhauſted receiver. 2. By immerſing the ſtem of a bolthead into a veſſel of water, and covering both with a receiver, then exhauſting the air out of both; on letting in the air on the ſurface of the water it forces it into the exhauſted bolthead. 3. A bottle that holds a wine quart being emptied of air, and weighed, is found to be about 17 grains lighter than when it is full of air, ſo that a quart of air on the earth's ſurface is 17 grains. 4. If a wet bladder be tied over the top of an open receiver, then ſet to dry, after which the air exhauſted from under it, the air's weight will then burſt the bladder with a ſurprizing report. 5. On a moveable plate place a tall receiver, open its cock and exhauſt the air out of it, then ſhut the cock, and immerſe the ſtem in which it is fixed into a veſſel full of water; on opening the cock the air's preſſure on the water will force it into the receiver in a beautiful fountain. 6. If an hole be made in the bottom of a cup, and have a bit of dry hazel or willow branch fixed into it, and this put into a hole on the top of a receiver; when quickſilver is poured into it, and the air exhauſted, the quickſilver will be forced thro' the pores of the branch by the weight of the incumbent air, and will fall in a curious ſhower into the receiver. 7. If a tube of 32 inches long, and open but at one end, be filled with quickſilver, and then the open end immerſed in a jar of quickſilver, that in the tube will ſink to the height at which it then ſtands in the barometer; if this jar and tube be put under a tall receiver, and the air exhauſted, the quickſilver will deſcend out of the tube into the jar; but upon admitting the air again into the receiver, its preſſure will drive up the quickſilver into the tube, and ſupport it therein as it ſtands in the barometer, which proves that the quickſilver in the barometer is kept up ſolely by the weight of the air. 8. If the air be exhauſted out of two braſs hemiſpheres of about 12 inches area it will require a force equal to 180 pounds to ſeparate them.

To prove that theſe effects are not produced by ſuction, and that there is no ſuch principle in nature. 1. Place a ſmall receiver at ſome diſtance from the hole in the pump plate, and cover it with a large one over the hole; on exhauſting the air the ſmall one will remain looſe while the large one is made faſt to the plate;

but on letting in the air the big receiver will be releaſed, and the ſmall one preſſed down. 2. If a pump be placed in water under a receiver and the air exhauſted, no water can be made to riſe in the pump. 3. If two movable plates be fixed on the pump plate, with communications between them that can be ſtopped by cocks, if the air is exhauſted out of a receiver placed on one of them, and then a receiver placed on the other, and the communication opened, half the air in the laſt will by its ſpring make its way into the firſt receiver, and both ſhall be fixed to the plates.

Breathing is in ſome meaſure performed by the power of the intercoſtal muſcles acting on the ribs; they are diſpoſed in form of a ſemicircular arch, and articulated with the *vertebra* of the back, behind, and connected with the ſternum before, which are the two centers on which they move: The diaphragma is a partition drawn acroſs the body dividing the thorax or cheſt from the abdomen or belly; it is a muſcle, and by its diſpoſition and ſtructure capable of expanſion whereby it becomes concave below, and of contraction whereby it becomes flat, and by this motion alternately rarefying and condenſing the air in the thorax, and thereby deſtroying its equilibrium, to reſtore which the air will preſs into the lungs, and when the diaphragma contracts, will be forced out again; hence the action of breathing, as repreſented by a lung's bladder, whoſe inſide has a communication with the external air, tho' it is incloſed in a thorax of glaſs with its bottom cloſed by a bladder tied flaccid repreſenting the diaphragma.

The elaſtic quality, or ſpring of the air is thus proved. 1. If an almoſt empty bladder be put under a receiver and the air exhauſted, the ſpring of the air in the bladder will then ſhew itſelf by ſwelling up the bladder as if it was blown. 2. If a little of the ſhell be cut off from the ſmall end of a freſh egg, and the egg put under a receiver, on exhauſting, the bubble of air in the big end of the egg will expand itſelf and drive out the contents of the egg. 3. If a fiſh in water be put under a receiver, and the air exhauſted, it's air bladder will ſwell the fiſh ſo as to make it ſpecifically lighter than water, and of courſe the fiſh will be buoy'd up to the ſurface. 4. If a cubic inch of dry wood in warm water, be put under the receiver, and the air exhauſted, large and innumerable bubbles of air will come out of the wood and make the water ſeem to boil; and in this manner may air be drawn viſibly out of the hardeſt bodies. 5. A withered apple in an exhauſted receiver will be plumped up, and look quite freſh, by the ſpring of the air in the inſide of it; and if a freſh one be pricked all over with a bodkin, and put in water under a receiver, on exhauſting, it will appear as if it was roaſting by a fire. 6. Put a glaſs of warm beer under the receiver, on exhauſting, the beer will boil over the veſſel by its ſpring. 7. If a tall receiver be exhauſted, and the neck of a veſſel joined to its bottom be half full of water, the ſpring of the air on the ſurface of that water will force it out into the receiver in a beautiful fountain. 8. If a little air be tied up in a bladder, and put in a convenient veſſel with great weights upon it, on exhauſting the air, the ſpring of the air in the bladder will lift the weights; and ſhew that its ſpring is equally forcible with its preſſure; therefore tho' a middle ſized man ſuſtains above thirty thouſand pounds weight on his perſon, yet the equal ſpring of the air within him makes him inſenſible of it.

HEAT and cold, or if you will the preſence or the abſence of fire, are the moſt uſual cauſes of the air's rarefaction and condenſation: If air be heated, it ſwells, ſo that the ſpace it poſſeſſed before it was heated will contain fewer particles than it did in its cold ſtate. Wind muſt be the neceſſary conſequence of this; for by what means ſoever the equilibrium of the air is deſtroyed, its neighbouring parts will never be at reſt till the balance is reſtored: Hence the reaſon why air ruſhes ſo violently into a glaſs houſe; into a cloſe room with a great fire in it; into warm towns, *&c.* When the ſun's heat is increaſed by the reflection of ſands, or the ſides of rocky mountains *&c.* the air will be rarefied, and by the ruſhing in of the colder neighbouring air, will be forced up into the higher part of the atmoſphere as light ſmoke is up a chimney by the heavier air. If a large cloud keeps the ſun's rays from the *air* under it, but rarefies *that* all round it, a wind will ruſh from beneath the cloud in all directions. Upon this principle alſo we account for the trade winds which conſtantly blow from the eaſt to the weſt about the equator; for as the ſun paſſes over the earth in that direction, and rarefies the air as he goes, the colder air will ruſh after him and cauſe the trade winds, if they are not diverted by vulcanos, burning ſands, mountains, *&c.* Hence alſo the monſoons; the day and night breeze on the iſlands in the Weſt-Indies; the wind from weſt to eaſt on the coaſt of Guinea; and the currents of Florida, Gibralter, *&c.*

'Tis unneceſſary to point out here how admirably theſe properties coincide with the general ſcheme of the creation.

LECTURE V.

PNEUMATICS.

THAT the air may be condenſed or ſqueezed into leſs room than it naturally poſſeſſes is proved, 1. By putting a blown bladder in a receiver; if a forcing ſyringe be then apply'd to the receiver, and a quantity of air forced into it, the bladder will be ſhrivel'd vel'd up by the ſuperior preſſure of the condenſed air. 2. If a copper ball be half filled with water, and a quantity of air forced into it as above, thro' a pipe that goes near the bottom of the water; if then a ſpouting pipe be ſcrewed on the other pipe, the ſpring of the condenſed air on the ſurface of the water will exhibit an amazing fountain. 3. The moſt formidable inſtance of condenſation is in the magazine, and walking cane wind guns; where the condenſed air has a ſpring capable of diſcharging 12 balls one after another with the ſame force as if charged with powder.

The reſiſtance of air is the reaſon why light and heavy bodies deſcend not equally ſwift; proved, by ſuſpending a guinea and a feather upon the top of a tall receiver; if they are dropped in vacuo at the ſame inſtant, they will at the ſame inſtant reach the bottom.

By compounding certain bodies, an aſtoniſhing quantity of air will become condenſed in the pores of the new body; of this kind are the grains of gunpowder, to which if fire be applied, the condenſed air will be greatly rarefied, and its ſudden ſwell being reſiſted by the adjoining air will cauſe an exploſion: For this reaſon gunpowder fired in vacuo can make no exploſion.

Sound is cauſed by any thing that can give a tremolous motion to the air; this vibration ſtriking upon the outward ſhell of the ear, is from thence conveyed up the auditory tube, and ſtriking againſt the tympanum, or drum, is ſo increaſed, that in making its way up the labyrinth, it gives a ſhock to the auditory nerves inſerted in it, and there conveys to the ſoul the idea of hearing, or ſound. The artificial ear makes this very evident. And the clock ſtriking in vacuo without being heard is a proof that ſound cannot exiſt without air.

When the atmoſphere is light, the corrupt air pent up in the cavities of mines (communicating with the outward air) will by its effort to reſtore the equilibrium ſwell into the mine, and hence the ſuffocating damp which is met with in mines when the barometer falls. This damp is made on the air pump by letting the air into an exhauſted receiver, thro' the flame of charcoal, ſulphur, or a candle; into which if an animal be put it is immediately ſuffocated. The fire-damp proceeds from the ſame cauſe, only that its particles are of an inflamable nature as riſing from the ſulphurous, nitrous, or oliaginous ſtratas in the mine: This taking fire by the lights uſed by the workmen, will run like a train of gunpowder thro' the works; and as it is confined, the elaſticity occaſioned by the heat will cauſe ſuch exploſions as frequently blow up the mine. This damp is made on the pump by letting the air into an exhauſted receiver through the flame of the oil of turpentine; after which if a lighted candle be put in the vapour it will take fire.

As the pores and cavities of all bodies are filled with air, an animal put under a receiver, and the air exhauſted, will ſoon die; becauſe as the air draws out of the lungs, *that* in the thorax will expand and ſwell the animal, ſhrivel up its lungs, and thereby ſtop the whole animal mechaniſm.

THAT water is preſent in air, is evident from ſeeing it precipitate in a cloud as the receiver is exhauſting; from the dew depoſited on Windows when water is brought into an hot room; from the wet hair of thoſe who aſcend the tops of mountains; and from its entering ſpunges and hygrometrical inſtrument, from which it is evident that air is a menſtuum for water in proportion to its heat and denſity: But as dry air is not diſpoſed to receive heat even from a burning glaſs, if it was not ſaturated with water, it would be almoſt impoſſible to rarefy it by heat; therefore this abſorbent quality takes up the water from a bleacher's yard *&c.* more in ſpring than autumn, and tho' water is ſo much heavier than air, the rarefaction of which moiſt air is ſuſceptible makes it lighter than dry air, and of courſe it muſt aſcend into the higher parts of the atmoſphere, and the dry air deſcend: But as the reflection of the earth's ſurface will neceſſarily heat the lower parts of the atmoſphere more than the higher, the cold of the upper regions of the air, the winds *&c.* will condenſe the moiſt air into drops too heavy for the atmoſphere to ſuſtain, and then it will deſcend in rain; while the dry air is as it were abſorbing *its* load of water to take up alternately into the higher regions. The earth affords more moiſture than the ſea, 1. From its inequality of ſurface, 2. From that ſurface being vaſtly encreaſed by vegitables, leaves, trees, *&c.* Therefore, as land air is more moiſt than ſea air, rain is duly diffuſed over the whole earth, even in climates where the ſun's exhalation muſt produce a very ſmall proportion of their rain.

When the ſmall particles of rain are froze before they come into drops, numbers of them being drove together by winds, or drawn together by their mutual attraction, will deſcend in flakes of ſnow. When the finiſhed drop is congealed in its deſcent it becomes an hail-ſtone.

LECTURE VI.

HYDROSTATICS.

THIS ſcience treats of the *nature*, *gravity*, *preſſure*, *and motion of fluids* in general; and of weighing ſolids in them. *Water*, like *air*, conſiſts of *round* and *hard* particles, as is proved by putting ſalt in water without

out encreaſing its *bulk*; and by the *Florentine experiment*, which forces water through the pores of a copper ball: Hence 'tis evident *there are vacuities in fluids*, and that no fluid can be preſſed into a *leſs ſpace* than it naturally poſſeſſes except *air* and *ſteam*.

Fluids are ſaid to be *perfect* or *imperfect* as their parts ſlide with more or leſs eaſe over one another, therefore quickſilver is the moſt perfect of all fluids. Water being of the *imperfect* kind is ſeldom *pure:* It adheres to any ſubſtance it meets with, mixes with its particles, and thence becomes impregnated with whatever *ſtratas* it runs over: If water has come over an *alkaline ſtrata* the *ſyrrup of violets* turns it *reddiſh*; if over an *acid ſtrata* the *ſyrrup* turns it *greeniſh*; if over *iron ſtone* or *iron mine* a ſolution of *galls* turns it *black*; and if over an *alum ſtrata*, *oil of tartar* turns it *thick*, &c.

Water being *incompreſſible* will not be more *denſe* at the *bottom* than the *top* of the ſea; but will have the wonderful property of preſſing, *upwards* and *ſideways* as forcibly as *downwards* in proportion to its *perpendicular height*, without any regard to its *quantity*; for as each particle is quite free to move, it will move towards that part on which the preſſure is *leaſt*; and hence no particle or quantity of a fluid can be at reſt till it is *every way equally preſſed*. A fluid may therefore be conceived as made up of *perpendicular columns of particles*, and as divided into *imaginary ſurfaces* each an inch or more from one another, the loweſt preſſed with the weight of *all* the reſt, &c. hence a pipe fixed under the *moſt* ſurfaces will diſcharge the *moſt* water, &c.

To prove that fluids preſs in all manner of directions alike, take four *glaſs tubes*, open at both ends, but bent into all kinds of angles; theſe put in water near to their tops, the water will riſe in them to its own level. Or take a veſſel full of water with an hole at the *bottom of* *its ſide* of the ſame capacity as one in its *bottom*; and the two holes will be found to diſcharge the ſame quantity of the fluid in the ſame time.

THAT fluids preſs in proportion to their depth without any regard to their quantity, is evident, 1. From a *bladder* tied flaccid over one end of an *open cylinder of glaſs*; if water be poured into it, the bladder will bulge *downwards*; but if then it be immerſed in a larger veſſel of water 'till the ſurface of the water within the cylinder be *even* with that in the veſſel, the bladder will then be *flattiſh* as if it were not preſſed at all, for indeed it is then preſſed equally. If the cylinder be plunged *deeper* the bladder will be preſſed *upwards*. 2. *Lead* is about 11⅓ times heavier than its bulk of water, if therefore a piece be held tight to the mouth of a cylinder (open at both ends) by a ſtring within the cylinder, and let down into water above 11 times its thickneſs, the ſtring may be let go, and the upward preſſure of the water will hold the lead to the cylinder; but if the cylinder and the lead be raiſed 'till the lead is not 11⅓ times its thickneſs below the ſurface of the water, it will then fall off and ſink. 3d. If a Tube open at one end, and filled with quickſilver, have its open end immerſed in a baſon of quickſilver, hung ſo by ſtrings that it may be *let down* into a deep veſſel of water, according to the depth the veſſel is *ſunk* the mercury will *riſe a fourteenth part* in the tube, and demonſtrate that quickſilver is fourteen times heavier than water. 4. If lead with a *flat upper ſide* be put in the bottom of a veſſel, and a piece of *flat* wood be held on it while the veſſel is filling with water; if no water can get in between the lead and the wood to form an *upward preſſure*, the wood will be held on the lead by its own weight and that of the water above it. 5. If an *empty bottle* juſt made ſo heavy as to ſink in water, be corked, and ſuſpended at one end of a balance, and with its cork pulled out be immerſed in water and filled, it will require as *much weight* in the oppoſite ſcale to pull it up as will weigh all the water in it, which ſhews that fluids weigh juſt as much in their *own* element as out of it. 6. If a ſmall tube 30 inches long, open at both ends, and to one end (bent to a right angle) it has a *large bladder* tied; if then the bladder be put in a box, and a board be laid on it with 25 or 30*lb.* weight upon it, and water be poured into the tube, the bladder will raiſe the weights, tho' the bore of the tube ſhould be ſo ſmall, as not to hold an ounce of water. 7. *The preſſure of a fluid upon the bottoms of all veſſels whatever, is proportional to their baſes and perpendicular height without any regard to the quantities they contain*; for if on a looſe piſton ſuſpended on a balance a column of water of a foot be weighed it will be found to weigh as much as a column of water of the ſame height, tho' contained in a flanging veſſel that holds ten times as much. 8. If a *ſmall tube* be joined to a *very large one*, and the whole be bent in the bottom ſo as the two parts may be either *parallel*, or make *any angle*; water may be poured into *either tube*, and it will juſt riſe as high in the *other*, even though one ſhould contain ten thouſand times as much as the other does: This alſo ſhews that fluids preſs in proportion to their perpendicular heights without any regard to their quantities; that water in pipes will aſcend to the *level of the ſpring* from whence it came; and that *jets* or *fountains* would riſe the *ſame height*, if not obſtructed by *angular turnings*, and the *reſiſtance of the air* into which they play.

Smoke does not riſe into the air becauſe of its *poſitive levity*, but becauſe it is *lighter* than the air where it is produced; hence if the ſmall neck of a bolthead full of water be immerſed in a glaſs of wine, the *lighter wine* will aſcend up into the bolthead, and the *heavier water* deſcend into the glaſs. For the ſame reaſon, a body ſpecifically (or bulk for bulk) *heavier* than water will ſink in it; a body of the *ſame weight* will lie indifferently any where in it; and one ſpecifically *lighter* will of courſe ſwim in it.

A *ſyphon* acts agreeable to that *equal ſtate* which nature affects through all her operations; it will not run unleſs the weight of water in the *outer* leg, be greater than that of the *inner* leg above the water in which it is immerſed, as the water falls therefore from the *outer leg*, it will make a continued *vacuum*, and of courſe the *preſſure of the atmoſphere* on the ſurface of the water, will force it thro' the ſyphon in a *continued ſtream*, if kept free from that lodgment of air which frequently takes place on the top of the ſyphon. By the *Tantalus' cup*, and *fountain at command*, the cauſe of *intermitting ſprings* is explained thus;

Clouds being attracted by the mountains give a continued ſupply to thoſe reſervoirs of water which are frequently found in the bowels of the mountains, and which ſupply *ſprings* in general; But ſhould the channel from one of theſe reſervoirs be formed like a *ſyphon*, of courſe the ſpring which proceeds from it will *ebb and flow* like thoſe in Derbyſhire, Berkſhire, *&c.*

A *capilary*, or ſmall tube, will by its *concave ſurface attract the water in which it is immerſed above the level*; *ſand*, *ſugar*, or any ſpungy body may be conceived as made up of theſe kind of tubes, and we find water will riſe in them above its *level* accordingly: hence the little channels of ſand which run like *veins and arteries* thro' the earth, conveying water from *ſubteraneous reſervoirs*, and the *ſea* itſelf, and forming thoſe lodgments of *ſea ſhells*, *fiſh bones*, *&c.* in the caverns of Derbyſhire *&c.* If a branch of one of *thoſe* channels come to the ſurface of the earth a *ſpring* will be formed by *that* means alſo; and happily ſupply thoſe *level countries* that are *too far diſtant* to be ſupplied by the *mountains*.

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LECTURE VII.

SPECIFIC GRAVITIES, HYDRAULIC ENGINES, &c.

A *Pipe* fixed *four times* as deep below the ſurface of a fluid as another of the ſame diameter will diſcharge *twice* as much in the ſame time; if 9 *times* as deep, it will diſcharge *thrice* as much; if 16 *times* as deep *four times* as much, *&c.* agreeable to the ſquare root of the depth: And the *velocity* with which a fluid ſpouts at any depth below the ſurface, is equal to that which a body let fall *that height* would acquire. Pipes alſo diſcharge a fluid (when placed at equal depths below the ſurface) agreeable to the ſquares of their diameters, i. e. a pipe *twice* the diameter of another will diſcharge *four times* as much of the fluid, in the ſame time; *thrice* the diameter, *nine times* as much; *four times* the diameter *ſixteen times* as much, *&c.*

FLUIDS *preſs* or *reſiſt* according to their *denſity*; and hence a boat will carry more on *ſalt* than freſh water. *The hydrometer* ſhews *this* very perfectly; 'tis buoyed up by *ſalt and water* mixed with *vinegar*, *&c.* but ſinks in *wine*, *ſpirits*, *&c.* according to their lightneſs, and hence 'tis uſed for trying the lightneſs or ſtrength of liquors.

IF a ſtick be counterpoiſed on a ſcale beam by water, and after that immerſed in a veſſel full of water, it will cauſe ſo much of the water to flow over the brim as will be ſupplied by *that* in the oppoſite ſcale: Hence 'tis evident a *ſhip* diſplaces juſt ſo much water in the ſea as is equal to its own weight and cargo: And hence alſo the *ſtrength of wood* may be judged of; for if a piece of oak of a foot long be immerſed in a narrow veſſel of water it will be found to ſink about $\frac{8}{10}$ of its length: Beech about $\frac{7}{10}$: Mahogany $\frac{7}{10}$, *&c.*

A ſolid body heavier than its bulk of water, will loſe juſt ſo much of its weight when ſuſpended in it, as its bulk of water weighs: But the weight loſt by the ſolid is gained by the fluid. Hence if the weight of a body in air, be divided by what it loſes in a fluid, the quotient will ſhew how much heavier it is than its bulk of that fluid; or its ſpecific gravity. By this tryal *pure gold* is found to be 19.637 times as heavy as its bulk of water; *Guinea gold* 17.793 times as heavy: *Quickſilver* 14 times: *Lead* 11.325 times: *Standard ſilver* 10.535: *Copper* 9: *Plate braſs* 8: *Steel* 7.85: *Iron* 7.645: And *block tin* 7.32. A cubic inch of braſs loſes 253$\frac{1}{3}$ grains of its aerial weight in water: In proof ſpirits it loſes 235 grains; therefore a cubic inch of water weighs 253$\frac{1}{3}$ grains; and a cubic inch of proof ſpirits 235 grains; And the ſpecific gravities of *pure ſpirits*, *proof ſpirits*, and *water* are as 840, 923, and 1000. From hence may be conceived the great uſe of the hydroſtatic balance.

THE action of the *common pump* depends on the *preſſure of the atmoſphere:* When the piſton is raiſed above what is called the ſucking valve, it cauſes a vacuum and the water will be forced up 33 feet, but not higher; which ſhews that a column of water *that* height is equal to the weight of a column of air of the ſame thickneſs reaching from the earth's ſurface to the top of the atmoſphere. Therefore at any diſtance above the well leſs than 33 feet the piſton will work, and water from thence may be lifted to any height whatever. In a *forcing pump*, the piſton is *a ſolid plunger*; it raiſes the water above the ſucking valve as in the laſt, but when the plunger deſcends (as the water cannot return thro' the valve back again) it forces it into a large air veſſel which communicates with the body of the pump above the ſucking valve; and as by this force the air in the veſſel becomes condenſed, its action on the water cauſes it to flow thro' a ſmall pipe in a continued ſtream. The engine for extinguiſhing fires conſiſts of two ſuch forcing pumps, with their air veſſels.

The *lifting pump* can only be uſed in deep water, as its piſton is worked by a rod going in at its bottom, and faſtened to a frame coming up each ſide of the pump: This piſton has a valve opening upward, and it works below the ſurface of the water in which the pump is immerſed, and thence has no occaſion for the air's preſſure, or a ſucking valve. This pump is generally equipt with an air veſſel as the laſt. On theſe principles engines are made for raiſing water above the level of rivers or ſprings; but if three pumps are worked in any engine by a triple crank and all of them throw their water into one pipe, there is no occaſion for an air veſſel, becauſe there will be always one or other of the piſtons acting ſo as to force the water out in a regular ſtream.

The *bucket engine* for raiſing water by pumps out of mines *&c.* is well calculated for ſituations where the ſtream that carries it has 3 yards of fall, and is too ſmall to carry a wheel: The bucket hangs on one end of a beam like that of a fire engine; and at half the diſtance from thence to the fulcrum hangs the pump rods; on the other end of the beam hangs a counterpoiſe, rather heavier than the empty bucket, and the column of water on the piſton; but when the bucket is filled by the ſtream, *it* is heavier and deſcends; the bucket hangs on centers a little on one ſide the center of its gravity, ſo that one ſide is heavier when empty, and the other when full, and being unlocked by its deſcent, its unequal poiſe turns and empties it, and then it aſcends and opens a valve which again lets the ſtream into it, and makes it deſcend again. This motion works the pumps.

Two forcing pumps for ſupplying houſes with water, are alſo worked by an engine of ſimilar principles, but with ſtill greater ſimplicity: A beam inclining downwards to each end from the center on which it hangs, has a trough cut in it, from a diviſion in the middle down to each end, where buckets are fixed for receiving the water that works it, and which flows into the trough, firſt on one ſide the diviſion and then on the other, as the ends riſe and fall: When one bucket deſcends, the valve in its bottom falls on a pin, which opens it, and lets out the water; mean while the ſtream is filling the other bucket, which when full, deſcends in like manner, and each end works a forcing pump.

THE *centrifugal machine* claims ſtill greater merit in force and ſimplicity; its ſhape is like the letter T, 'tis hollow throughout, and its three ends are open: When the loweſt end is immerſed in water, and it is whirled round on that end, the air in the arms will be partly thrown out by the centrifugal force, and conſequently the preſſure of the atmoſphere on the ſurface of the water into which it is immerſed will force it up the tube and throw it out at the arms; hence a continued vacuum is made, and of courſe a continued ſtream thrown out. The perpendicular tube muſt not be above 33 feet feet high for reaſons already given. Two men will diſcharge near three times as much water with this machine in the ſame time as with any pump yet invented: The inventer had one hundred guineas premium from the ſociety; and 'tis now fitting up on board the king's ſhips.

The Duke of Bridgewater's curious colliery at *Worſtley* ſix miles from *Mancheſter*, lies on a level with the general part of the country, tho' upwards of forty yards beneath the ſurface; this circumſtance gave the opportunity to open a navigable canal thro' the ſide of the hill up to the mine, which both drains the ſeams and conveys the coal to Mancheſter in long narrow boats that can ſail under ground to the very works; This ſubterraneous paſſage is near a mile in length, about four feet wide, and five high above the water; is arched with brick, or ſolid rock; and has ſeveral openings up to the ſurface to make a free circulation of freſh air. About a mile from Worſley the canal croſſes the river Irwell at Barton-Bridge over an aqueduct of ſtone 200 yards long, and 25 high; here the boats of the *old navigation* ſail under thoſe of the *new*; two great roads alſo paſs under it. From hence it extends to *Mancheſter* and ends in a large baſon made both to contain the boats, and give the water of a river, taken into it here an opportunity of ſpreading itſelf round a curious wear, that in caſe of a flood takes off the abundant water; by theſe kind of wears properly placed the canal is prevented from riſing above its due level. Out of this baſon the boats paſs under an huge ſubterraneous arch of brick under the adjoining hill, and have their contents taken up thro' an opening in the ground (by a curious machine worked by a ſubterraneous river) and diſcharged ſo high as to deſcend on an inclined plane as it were into the town. In all convenient places there are flood-gates in the bottom of the canal, two of which being ſhut the intermediate water can be let out, and the bottom repaired, the fiſh taken &c. and in caſe of a breach, they ſhut themſelves. Œconomy and ſtrength are diſtinguiſhable in every part of this work: Bridges, placed at ſeveral miles diſtance were formed in the quarry; a floating ſmithy and joiner's ſhop followed the work; boats carried the rubbiſh of one place to fill up another, for carts were never uſed; the walls under water were made perfectly ſolid, by running mortar and ſand between the ſtones with water conveyed in ſmall pipes from the canal; and one man's work made ſo immediately to depend on another's, that one could not ſtop without diſconcerting all the reſt. At Stretford the country falls ſix yards below the level of the canal for a full mile, to fill up which a caſſon or artificial canal was formed of deal balk of 40 yards long, 17 wide, and 6 deep, which being filled with water from the canal, boats with opening bottoms could ſail in and diſcharge their loads without trouble, and fill it up to the level; the caſſon was then ſhifted farther &c. 'till the canal was carried by that means over the valley: This method prevented the land carriage of the earth to raiſe it, and by the earth falling thro' the water and lying in it, it became ſolid enough to ſupport the canal on its top. The deſign of this work is *twofold*, an extenſive *coal-mine* is worked to great advantage by means of it: And in a few years it will open a communication between the large trading towns of *Mancheſter* and *Liverpool*, like thoſe in *Holland*; and as the trade of the two towns have the moſt intimate connection; not only *their* inhabitants, but *thoſe* of the intermediate countries will derive many permanent and laſting advantages from it.

LECTURE VIII.

ELECTRICITY and MAGNETISM.

THE general properties of *air* and *water* being defined, thoſe of *earth* and *fire* follow of courſe.--- *Air* and *water* are volatile, and eaſily ſeparated by fire from the bodies they help to compoſe: *Pure earth* reſiſts the utmoſt force of fire, ſo that what remains of a body after it hath been expoſed to the fierceſt fire may be conſidered as (nearly) *pure earth.* *Fire* is the moſt powerful agent in the decompoſition of bodies, for its particles being infinitely ſmall, and agitated by a rapid motion, it eaſily penetrates the hardeſt bodies. Fire is alone *eſſentially fluid*, and the principle of fluidity in others, by ſeparating their parts; hence *air* itſelf might become ſolid, if it could be entirely deprived of the fire it contains, as bodies of the moſt difficult fuſion become fluid, when penetrated by a ſufficient quantity of the particles of fire. The greateſt degree of heat producible by man, is that excited by the rays of the ſun collected in the focus of a large *lens* or *burning-glaſs*. All bodies contain fire, for any body violently agitated grows hot; yet heat is nothing but an idea in us, produced by the greater or leſs motion of fire, and in which the judgment of our ſenſes is wholly uncertain. When a body gives fire a motion in *right lines*, it is lucid, and excites by its flow on the retina of our eyes the idea of light; but heat will move in *oblique lines:* Yet there is not always *light* when there is *fire*, and yet there cannot be *light* without *fire*, tho' in the *ignus fatuus*, *rotten wood*, *dry fiſh*, *&c.* we cannot perceive it becauſe it is leſs hot than our bodies. *Quickſilver* when it plays into an exhauſted receiver in the dark produces a ſtrong light. *Phoſphorus* alſo contains much fire, but the water in which it is put keeps it in: *Air* alſo partly keeps in the fire in hot water, for if one of two veſſels equally full of hot water, be exhauſted on an air pump, the fire will eſcape and make it but luke warm when the other is ſtill hot. *Flame* is the vapour heated *red hot*, which is emitted by the burning body.

It is evident there is an *elementary*, (or what is called *electric*) fire of ſtill greater ſubtilty than this: It is inherent in moſt ſubſtances, and will be conducted by them to any diſtance, excepting ſome of the *excrements of nature*, as *ſilk*, *&c.* ſome ſay this fire is the cauſe of all motion; that the animal ſpirits are electric fire; that it is the ſoul of, and moves the ſolar ſyſtem, *&c.* Its properties and effects are truly wonderful, and are principally theſe. 1. If a long tube of glaſs be rubbed all one way with a warm hand or cloth, an atmoſphere

of

of this fire will be formed all round it, and if a finger approaches the tube the fire will come viſibly off the tube into the finger with a ſnap: The reaſon is, the friction collects the fire, and the ſpark is the effort it makes to diſperſe itſelf again, and thereby reſtore its equilibrium. 2. If the ſame tube electrified, approaches a *feather* hung by a ſilk thread, it will *attract* the feather once, but if held to it again will *repel* it. The ſilk will not conduct the electric fire; the equilibrium is therefore effected between the tube and the feather on the firſt approach; on the ſecond, the atmoſphere of the tube preſſing on that of the feather, drives the feather from it; but if the feather be ſuſpended by a flaxen thread, the electrified tube will always attract it, becauſe the fire can make its eſcape up the thread and thereby leave a continued inequality between them. A large globe or cylinder of glaſs, with a cuſhion to produce the friction, a prime conductor to take off the the electric atmoſphere from the glaſs, and depoſit it in a glaſs receiver covered with tinfoil to within two inches of the top, and a wheel to put the cylinder in motion, is called the *electric machine*, or *fire pump*; when this machine is put in motion, it deſtroys the equilibrium of the *electric fire* about it, and from thence the whole of its phenomena proceed, as may be proved by experiment, 1, If a perſon touch the electrified conductor, the fire will eſcape thro' the perſon into the ground, with a prodigious flaſh and report. 2. If any number of perſons take hands, and the firſt perſon holds a chain which communicates with the *outſide* of the receiver, and the laſt perſon touches the communication with the *inſide* when the phial is charged, the fire will reſtore itſelf thro' all the company at the ſame inſtant, giving each a ſevere ſhock at the wreſts and elbows in its paſſage to the earth. 3. If a perſon ſtands on a ſtool with *glaſs feet*, and holds a chain faſtened to the conductor, on turning the machine, and touching him, ſparks may be brought out of every part of his perſon and cloaths; which ſhews that the electric fire is chiefly pumped from the earth, and cannot return to it again thro' glaſs. 4. If a ball be hung on the conductor, and a plate of *bran* or *leaf gold* be placed under it, on electrifying the ball, the bran will be alternately attracted to and repelled from it in a beautiful ſhower; here, the particles of the bran are the carriers as it were of the electric fire from the ball to the plate: And if two *bells* be hung on the conductor, one by a flaxen thread, and the other by a ſilk thread (having from it a chain to the table,) if a ſmall *clapper* be hung between them on a ſilk thread, it will carry the fire from one to the other and thereby ring both. 5. *Electrified feathers* ſpread out their threads radically; if a round body be held to them they *cling* to it and depoſit their fire; but if a point be held near them they *ſhrink* at once, becauſe the pores of the point are better diſpoſed to receive the fire *inſtantaneouſly* than the round body; hence the reaſon why the wires on the *American houſes* have all points to receive with more eaſe the *electric lightning* from the clouds, and thereby prevent its miſchief: This experiment alſo demonſtrates why the *ſenſative plant* ſhrinks at the touch. 6. If *wires* fixed like the ſpokes of a wheel be ſuſpended on their center, with their points bent all the ſame way and in the plane of the circle; on being electrified, the effluvia flowing from the points will ſtrike ſo forcibly upon the air as to force the wheel round with great rapidity. 7. *Water* and *ſalt* (like the cylinder and cuſhion) will collect the electric fire when put in motion, for one is an *electric* and the other a *non-electric* body; hence the *ſea* itſelf becomes as it were an *huge electrical machine* when violently agitated by winds, collecting on its troubled ſurface the fire from beneath, and looking in the night as if it was all in flames. *Clouds* raiſed from a ſea ſo circumſtanced, muſt needs contain more of the electric fire than clouds raiſed from the land, or a calm ſea; if therefore two clouds meet, fraught with *unequal portions of this fire*, the cloud *more* electrified will depoſite its abundance in the cloud *leſs* electrified, and with a flaſh of lightning reſtore the equilibrium; this fire driving away the air, the adjoining air will ruſh in, and with a report called thunder reſtore the equilibrium of the air. If a cloud attracted by a neighbouring mountain contains *more* electric fire than the mountain, the lightning will dart from the cloud to the mountain, and vice verſa; hence if an electric cloud comes too near a *tower*, *tree*, *houſe*, *&c.* and they are not wet, the fire will deſcend on them in an effort to reſtore the equipoiſe, and if greatly obſtructed in its paſſage to the earth will perhaps break them all to pieces; to be dry, or ſtand under a tree or ſhed is therefore dangerous in a thunder ſtorm; and ſhews alſo the extream utility of having a wire from the ground to the top of any tall building, down which the equilibrium will be reſtored without danger, and if a finger at that time be applied to the wire it will give the *electric flaſh* much ſtronger than by any machine. A *kite* ſent up into the thunder cloud by a wet packthread, having a key tied to its end and held by a ſilk ribband, will extract the fire from the cloud, it will come down the wet ſtring, and ſtream off the key to the ground in a beautiful, but alarming torrent of fire.

'TIS thus, by weight and meaſure, the *Almighty* has provided ſelf-phyſic for the diſorders of his works!

SOME hold *electricity* and *magnetiſm* as relations, becauſe *iron* ſtruck by lightning acquires *polarity*, and *magnetic attraction*. The *loadſtone* and *iron* are called male and female, becauſe of their likeneſs, and attracting nothing but one another. One *Magnus* a ſhepherd firſt diſcovered this wonderful ſtone from its ſticking to the iron in his ſandals, and from him it had its name: Its attraction is at two points called its *poles*, and if the ſtone was broke in a thouſand pieces, each piece would have its attracting poles; this attraction is ſtrongeſt in *contact*, and diminiſhes by a proportion not yet ſound out, but that pole of the ſtone which atttracts one end of a touched needle, will repel the other. *Flavius Gio* of Naples, about three hundred years ago, firſt diſcovered that a piece of iron rubbed on it, and then ſuſpended, had the property of pointing *north* and *ſouth*, and thence apply'd it to *navigation.* An hundred years after it was found by *Sebaſtian Cabot* to have varied a-above 11 degrees eaſt from its firſt point, and at this time it is near 20 degrees to the weſtward, ſo that in 1900 years it will have made one entire revolution. This variation of variation Dr. *Halley* attributes to a prodigious loadſtone in the center of the earth, which he ſuppoſes has neither of its poles in the earth's axis; nor preciſely the ſame revolution.

Artificial Magnets may be thus well made; Lay four ſmall bars of iron touching one another in a line, lengthwiſe; ſlide one pole of a magnet from the right hand to the left over them ſeveral times, and they will be good magnets: But if then you ſlide the ſame pole over them from the left hand to the right, the magnetic virtue will be entirely taken from them. If ſeveral bars be firſt bent like an horſe-ſhoe, and two at a time joined (ends together) run over as above, then the whole made up into one magnet, in a caſe, with north poles together and ſouth poles together, this aſſemblage will make *one* exceeding ſtrong magnet. *Fire* and *ruſt* only can deſtroy the power of theſe magnets, tho' time will weaken them, if as much iron as they can poſſibly ſupport, hang not continually on them. To recal the decreaſed virtue of a magnet, hang a large *ſand bag* to the iron adhering to it, and keep every day encreaſing the ſand.---To give the virtue to a *knife*, draw it over either pole from hilt to point ſeveral times. To ſee the lines in which a magnet attracts, lay on a *bar magnet* a piece of *window glaſs*, with a ſmooth paper upon it, on this ſtrew a few *ſteel filings*, and the *magnetic rays* will appear in many *beautiful curves*

PATENT OFFICE

LECTURE IX.

MECHANICS.

SIR Isaac Newton's three laws of motion are the foundation of mechanics: The firſt is, That matter being inert, is of itſelf perfectly indifferent to either reſt or motion. 2d. That bodies move in proportion to the force that acts on them. And 3d. That action and reaction are equal and contrary. Whatever is inconſiſtent with theſe laws, is ſo with the general conſtitution of nature.

The *momentum* or force of a body, ariſes from its quantity of matter, being mutiplied into the velocity with which it moves: Thus, if a *battering ram* be 1000*lb.* weight, and the velocity with which it ſtrikes a wall be 20, then is its momentum 20,000: But a cannon ball ſhall do the ſame execution if its quantity of matter be no more than 10*lb.* provided it be thrown with a velocity equal to 2000, for 10×2000=20.000, ſo that the momentum of both are equal. Proved by a ſpring throwing half the quantity of matter twice as far as the whole: And by 8*lb.* being counterpoiſed by 4*lb.* at twice the diſtance from the fulcrum of the balance: Hence the force, or power of any machine, whether ſimple or compound, is eaſily computed; for when two bodies are thus ſuſpended upon any machine ſo as to act againſt one another, if the perpendicular aſcent of one body be to the perpendicular deſcent of the other in the inverſe ratio of their weights, they will balance one another; and therefore ſo much quicker as the power moves than the weight, ſo much is the advantage gained by the machine, and gives this mechanical axiom, That what is gained in power by any machine, is loſt in the time of working it.

All kinds of mechanical engines conſiſt more or leſs of theſe ſix mechanical powers, *viz.* the *lever*, the *wheel* and *axle*, the *ſyſtem of pullies*, the *inclined plane*, the *wedge*, and the *ſcrew.* The *lever* is a bar turning upon a prop or center, and is uſed either to raiſe weights or overcome reſiſtances: There are three kinds of levers, and in each of them, the velocity of each point is directly as its diſtance from the prop. When the prop is between the weight and the power, 'tis called a lever of the firſt kind; ſo much as the power is farther from the prop than the weight is, ſo much is the advantage gained by the power over the weight. Iron crows, ſciſſars, pincers, *&c.* are *levers* of the firſt kind. A lever of the *ſecond kind* is when the weight is between the prop and the power, as in doors turning on hinges, rudders of ſhips, oars, and ſuch knives as are fixed at the point, A lever of the *third kind* is when the power is between the weight and the prop, like the bones of our legs and arms, the wheels of clocks and watches, a ladder reared againſt a wall, *&c.* The bended lever differs in nothing but form from the firſt kind, its power is the ſame and 'tis like an hammer drawing a nail. In each of theſe, ſo much as the power moves farther or ſhorter than the weight ſo is the advantage or diſadvantage of each. The power of a compound lever is found by multiplying the power of each into one another.

In the *wheel* and *axle* the advantage of the wheel over the axle, is as their diameters, i. e. if the wheel be four times as large as the axle, a man may lift four times as much by it as by his own ſtrength allowing for friction. This machine is the principal part of a common crane. *Upper pullies* that are fixed only ſerve to change the direction of the power, and give no mechanical advantage thereto; but the under block of pullies moving with the weight, give an advantage proportionate to the number of ropes by which the weight is ſuſtained; and which may be eſtimated alſo by ſo much as the power moves faſter than the weight.

The *inclined plane* gains an advantage over the weight to be raiſed by it, in the ſame proportion as the height is to its length, i. e. I ſhall roll a cylinder up a plain three yards in length, and but one yard high, with thrice the eaſe I could lift it perpendicularly that yard, *&c.*

A *wedge* is but an inclined plane of another form, and its power is as the thickneſs of its back is to the length of one of its ſides, *&c.*

The *ſcrew* may be conſidered as an inclined plane wrapt round a cylinder; therefore as the power moves round the cylinder, while the weight riſes the diſtance of the *threads* from one another, the power over the weight, is as the velocity of the power to the velocity of the weight.

In a *common jack* we have all theſe powers together, if to an arm of the fly the power be applied; and ſo far as that power moves farther than the weight, ſo much is the advantage which the power has over the weight.

The center of gravity of a body is a point round which all parts of the body balance each other; therefore if this center is not ſupported the whole will fall: If therefore a perpendicular be let fall from the center of gravity, and it falls within the baſe or ground on which the body is placed, the body will ſtand; otherwiſe not. If the center of gravity lie perpendicularly above or below the *center of its motion* the body will be at reſt; if not it will vibrate till it comes to the latter ſituation. Hence bodies will ſtand on a point; others may be made to roll upwards, *&c.*

Bodies deſcend by the power of gravity with an accelerated motion, i. e. if they fall one rood in the 1ſt. ſecond of time, they will deſcend 3 roods in the 2d. ſecond; 5 in the 3d. ſecond; 7 in the 4th. 9 in the 5th. *&c.* agreeable to the odd numbers 1, 3, 5, 7, 9, 11, 13, *&c.* and to the ſquares of the times; that is in the 4th. ſecond the body will be fallen 16 roods; in the 5th. ſecond 25 roods; in the 6th. ſecond 36 roods, *&c.* Proved by a projected ball falling one inch from a ſtraight line in the ſame time it falls 3, 5 inches *&c.* forming a parabola, as all riſing or falling bodies do that project out of the line of gravity. Hence the reaſon why a ball or ſpouting fluid goes the greateſt diſtance on an horizontal plane when 'tis elevated to 90 degrees; that a ball droped from the maſt head of a ſhip underſail ſhould fall in a curve to the bottom of the maſt; and that a gun placed perpendicular on a carriage, and fired when the carriage is in a ſwift and ſtraight motion on an even plane, ſhould diſcharge the ball ſo as to deſcribe in the air a parabola, and meet the gun in its fall, *&c.*

Pendulums vibrate according to the ſquares of their lengths; i. e. a pendulum four times as long as another will but vibrate ½ ſo faſt; one 9 times as long, but ⅓ ſo faſt; one 16 times as long, but ¼ ſo faſt, *&c.* The center of a pendulum's oſcilation is that point in it, where if on each ſide of it, the quantity of matter was multiplied into its motion, the two products ſhould be equal. By this rule the center of oſcillation in a vibrating rod, is found to be at two thirds its length from the point of its ſuſpenſion; for the *two thirds* multiplied into its motion, is equal to the *other third* multiplied into its motion. Hence the moſt effectual blow is ſtruck with a ſtick at two thirds of its length from the hand. A pendulum 39.2 inches from its center of motion to its center of oſcillation will vibrate ſeconds. Could pendulums vibrate in the curve called the cycloid, a long or ſhort vibration would be performed in the ſame time: And the pyrometer ſhews that metals expanding by heat and contracting by cold will cauſe very different vibrations in hot or cold climates.

LECTURE X.

MECHANICS.

IF machines could be made to move without friction, the leaſt degree of power added to that which balances the weight would be ſufficient to raiſe it: But as the ſmootheſt bodies are full of pores and little eminences, theſe will lock into one another in rubbing bodies, and greatly retard the motion of a machine,---hence the friction in the *lever* and the *wheel* and *axle* is very ſmall: In *pullies* it is very conſiderable: And in the *inclined plane*, the *wedge* and *ſcrew* it is very great. Friction is of two kinds, the *rubbing friction*, and the *friction by contact*,---the rubbing of the locked wheel of a waggon againſt the road may repreſent the *firſt*; and its manner of touching the road in its uſual motion, the *ſecond*. When the *firſt* kind of friction can be reduced to the *ſecond* there is a very manifeſt advantage given to the power of the machine, as is demonſtrated by experiment with the *friction wheels*; theſe wheels are hung ſo that their peripheries form an angle in which the gudgeon of the heavy wheel turns without wearing: *Water-wheels*, large *grinding-ſtones*, and even *wheel-carriages* are hung in this way to great advantage, and at a trifling expence. A broad rubbing ſurface has much the diſadvantage of a narrow one, tho' they each ſuſtain the ſame weight, becauſe of more points and pores being in contact; hence the ſmaller the gudgeon or axle of a wheel the better, if it has but ſtrength to ſupport the weight. The friction in water that carries an underſhot mill is much taken of by a ſloping peddal; the velocity of the float boards of the wheel ought to be a third of the velocity of the water; the number of ſtaves in the trundle ought to be no even part of the number of cogs in the wheel that turns it; and the grinding ſtones ſhould not make above 60 revolutions in a minute.

The *mill for ſawing marble* depends on friction, for it's ſaws have no teeth but ſand waſhed under their edges; a water or wind wheel gives it motion by means of a crank, and a crooked lever; and a large flat ſtone is carried as a poliſher by the ſame motion.

Archimedes's ſcrew is a machine uſed for draining water out of ſmall pits; it conſiſts of *one*, *two*, or more hollow threads, open at both ends, and running parallel to one another round a center; one end is immerſed in the water, and the other ſo raiſed as to form an angle of about 45 degrees with it: As the ſcrew turns round, the *lower ſide* of it (where the water will endeavour to lodge) being turned to the *upper* alternately, forces up the water in a large current. As the air grows lighter the higher we aſcend in it, two contrary winds meeting will neceſſarily cauſe a whirlwind which will for that reaſon aſcend and form the ſcrew juſt mentioned; when this happens at ſea the water will be raiſed by it, and form that tremendous phenomenon the *water ſpout*.

Cranes chiefly conſiſt of the wheel and axle, a ſyſtem of pullies, and a projecting lever of the ſecond kind, which will turn the weight (after it is raiſed) on any ſide for the convenience of loading: They ſhould never be made without a *catch* to prevent accidents; or a lever, to be held faſt on the wheel while the weight deſcends.

The *common pile-driver* has a pulley fixed between two tall poſts, over which a rope goes to a wince worked by two men, and the other end of it has an hook which taking hold of the ram or weight raiſes it to the pulley where it is by a contrivance unlocked, and falls on the head of the pile; the hook immediately follows it and takes it up again, &c. But the *pile-driver* uſed at Weſtminſter-bridge was fixed on two boats, and ſo contrived that whilſt the horſes that turned it went conſtantly round, the weight was drawn up, and fell on the pile, and was followed by a pair of tongs, which took hold of the weight and drew it up again, without the horſes ſtoping or falling forwards, becauſe a large fly regulated the motion of the machine. Theſe tongs were nearly counterpoiſed by another weight, whoſe rope wound round a ſpiral fuſee, ſo as to cauſe the tongs to fall with a moderate and uniform velocity.

THE *upright cylindric mill*, is like a churn turning on a point in its bottom: It has ſix hollow arms, of half its length and $\frac{1}{5}$ its diameter, which communicate with the upright cylinder, and are fixed horizontally to its bottom. A ſmall hole is made on the *ſame ſide*, and near the outward end of each of the arms, thro' which the water which flows into the cylinder comes forcibly out, and by its *puſh* againſt the air, turns the cylinder the contrary way; this motion carries the mill-ſtones. This mill exceeds all others in ſimplicity, and is well adapted to ſituations where the ſtream is ſmall and has a good fall.

THE *new conſtructed wind mill*, has but two arms, and theſe are cloathed with half inch deal boards formed like little doors on each ſide the arm, and running on centers fixed at two thirds their length; theſe being held cloſe ſhut by a weight which acts thro' the axle of the mill wheel, will open *more* or *leſs* as the wind blows, and keep the mill from going too *faſt* or too *ſlow*, by either a great or ſmall blaſt. The *back-ſails* are made of the ſame materials, and hang perpendicular by two projecting arms from the cap of the mill; they are formed out of a circle, and twiſted to proper angles; an endleſs ſcrew on their axis turns a wheel which falls into the teeth of a fixed *contrite wheel* on the *wall plate* of the mill When the wind changes theſe ſails are put in motion and bring the other to *face the wind.* Two arms to a mill do not break the current of the wind into eddies ſo much as four arms do: And the ſails ſhould incline 30 degrees from a perpendicular to the wind near their center, and diminiſh gradually to about 5 degrees at their outward ends.

In *wheel carriages* the fore wheels are made lower than the hind ones, chiefly for the convenience of turning, and not for any advantage to the draught; for as each ſpoke of the wheels is a *lever* the longer it is the more is its power; hence the abſurdity of loading waggons on the *fore* rather than the *hind* wheels, where the obſtacles they meet muſt approach ſo much nearer a perpendicular to the draught than it does in the hind wheels. In *uneven roads*, the load lies perhaps the beſt in the *middle* of the waggon. *Broad wheels* are juſt as *eaſily* drawn on hard ground as *narrow ones*, and *eaſier* on ſandy ground becauſe they ſink not ſo deep; if the ſand indeed be *ſoft*, they will drive it before them, and clog themſelves. *Diſhed wheels* on a *ſtraight axle*, not only give a broader baſe for the machine to ſtand on, and thereby prevent its being overturned, but ſtanding perpendicular under the load when its center of gravity is thrown on one ſide, they are leſs liable to be broke down: but the *axle that inclines downwards* at each end tho' it gives more room to the waggon, is both more liable to be broke and overturned. *The line of an horſe's draught* is not parallel to the horizon, but inclines *upwards* at leaſt 30 degrees, his ſhoulder in particular is not perpendicular but inclines agreeable to that angle: But horſes in a *team* muſt draw parallel, and conſequently to a diſadvantage. It would perhaps be worth the enquiry, whether ſix horſes with each a light and properly-made cart would not draw more, with more eaſe to themſelves, than when they are all yoked to one. *Each of theſe are proved by experiment.*

THE *fire* (or rather *ſteam*) *engine*, is one of the nobleſt preſents that art has made to the neceſſities of mankind! When the particles of *water* are ſeparated by *fire*, they compoſe an *elaſtic vapour*, called *ſteam*; this vapour is capable of occupying almoſt 20,000 times the *ſpace* it did in its ſtate of *cold water*; 'tis of force ſufficient to drive away the air, and it may be condenſed, or brought back to water again by *cold*. (Theſe principles gave riſe to the *machine*). Hence a long hollow *cylinder* of iron communicates with an huge and cloſe *boiler* half filled with water, by a neck which can be opened or ſhut up by a ſliding valve called a *regulater:* The *cylinder* is exactly filled by a *piſton* made *air-tight*, that hangs on one end of a *beam* of timber about 20 feet long and ſuſpended on a center like a ſcale beam; at the other end of the beam hangs the *rods* which work the *pumps* in the bottom of the *mine*, and throw up a part of the water into a *reſervoir* on the top of the building: From this *reſervoir* there comes a *pipe* under and thro' the bottom of the *cylinder* that by opening a cock (called the *injection cock*) plays a *jet* of cold water into the *cylinder* to condenſe the ſteam; after which this water falls thro' a pipe (with a valve opening outward,) and forms the *hot well:* Another pipe alſo with a valve outward called the *ſnifting valve* is fixed near the bottom of the cylinder, and ſerves to let out the *air* or *ſteam* without letting it return. The *regulator* and *injection cock* are alternately opened and ſhut by a piece of timber hanging from the large beam; and a ſtream is let into the *boiler*, or ſtopped, by a floating *copper ball* in the boiler that regulates the height of the water. If now a *large fire* be put under the boiler, and the ſteam let into the cylinder by opening the regulator, it will drive out the air, and poſſeſs the ſpace itſelf; but ſo ſoon as the *injection cock* is opened, the *jet of cold water* will play into the ſteam in the cylinder, and *condenſe* it into a *few drops*; hence a *vacuum* is formed in the cylinder, and the *preſſure of the atmoſphere* on the *piſton* will force it down to the bottom of it; the ſteam then being let in again will counteract the air's preſſure, and with the weight of the pump rods on the oppoſite end of the beam, bring up the piſton to the *top* of the cylinder. This action is repeated *fourteen* or *ſixteen* times in a minute, and works the pump in the mine. As the *friction* of this machine is very great, inſtead of reckoning 15*lb.* preſſure on every ſquare inch on the piſton, 10*lb.* will be found nearer: If then the weight of a column of water, the depth of the mine, and the diameter of the pump be calculated, the neceſſary diameter of the cylinder will be eaſily found.

THE *fire engine with the inverted piſton* ſpares the expence of both a *beam* and *building*; the cylinder with its open end downwards, ſtands over the *pit* or *ſhaft of the mine*; the *boiler* ſtands by its ſide, the *injection well* above it, and to its *piſton* the *pump rods* are faſtened. The *regulator* (of great ſimplicity) is the *injection cock* alſo. When the ſteam is let in at the top of the cylinder, and condenſed by the injection water, the *upward* preſſure of the atmoſphere forces the piſton from the bottom to the top of the cylinder, and the weight of the rods, and ſtrength of the ſteam forces it back again. This motion works the pumps.

THE *cold water vacuum* will do this buſineſs with ſtill leſs *machinery* and *expence*, where the water that works it has a fall of 40 feet. With the bottom of the cylinder there communicates a perpendicular wide pipe of 33 feet long, having a regulator at its bottom, and another at its top. The piſton and beam are the ſame as in the common *fire engine.* The water being let in at the bottom of the cylinder will fill both the cylinder and the pipe below it; if then the regulator at bottom be opened the water will deſcend out of the *cylinder*, but not out of the *pipe*, becauſe it is *then* but a *counterpoiſe for the atmoſphere:* Thus a *vacuum* is formed in the cylinder and the piſton will *deſcend*, and ſhut the upper regulator; but when it reaches the bottom it opens it again, and as the cylinder fills, the piſton riſes. Thus action is given to the beam; and *water* applied in this way is perhaps the moſt *powerful agent* it is in any other. *N. B. For ought I know theſe two engines are new and unknown to the public.*

LECTURE XI.

FORTIFICATION.

MAN in what is called his civilized ſtate is the moſt inexplicable of all riddles! He ſeems the moſt *perfect animal* in the creation, yet his purſuits are more abſurd, and his life leſs happy than the *meaneſt.* He ſhakes of the *animal*, and adopts his *mental* faculties; and appoints the reins to a *chimerical reaſon*, inſtead of a more *wiſe inſtinct:* Hence *error*, *ſhadows*, and *diſappointment* are the attainments of his unmeaning life; and *murder*, *rapine*, *treachery*, and *madneſs* are the inſtruments of the acquiſition. Yet beauty and happineſs mark every other part of creation! The *all-wiſe*, the *good CREATOR* cannot be the author of *evil:* and *his* ſcheme in nature ſeems to have *continued the ſame* from the beginning, *conſummate*, and *all perfection!* If we then ſurvey *man* in a *ſtate of nature*, we ſhall find him an *animal* of a ſuperior order, without any wants but what his mother earth ſpontaneouſly produces for him: He went naked, and his maker gave him (e'er refinement ſpoiled it) a conſtitution to bear it; he lived at large the whole earth was his eſtate; and the want of property left him without care. To propagate his ſpecies; not to deſtroy them: To live joint tenant of the ſhade with his fellow creatures, and fellow cattle; without enſlaving them: and to enjoy that inſtinctive liberty in full latitude, (which even the moſt ſlaviſh cuſtoms cannot obliterate,) were his purſuits and his happineſs. Need we any other proof of this, than the inſufficiency of human laws to alter and methodize him? Are not the horrid devaſtations of war, often the awful efforts of *nature* to regain her native liberty? and indeed how often are ſtates under the neceſſity of bating the hook of ambition with that word! The ſoul of man is naturally full of *benevolence*, *openneſs* and *good-nature*, but *power*, *dependence*, and their unvarying *conſequences* deprave and intoxicate the worthieſt mind; as is evident from thoſe unhappy paſſions which artificial life has given birth to, both in governors and the governed. The happy ſavages of *Tartary* and *America*, before ſuperfluous neceſſaries were introduced amongſt them, led a life of nature, and ſimplicity agreeable to the deſign of their maker. Their perſons diſdain'd the ſhackles of cloaths, and their appetites craved no higher delicacies than (what the human ſtomach was intended to digeſt well, *viz.*) the natural herbs, fruit, and roots of their mother earth. *Care*, the inſeparable attendant on civilized life, and the poſſeſſion of ſuperfluous neceſſaries, never opprest the native liberty of their minds, for they had no outward property to be careful about. The human race naturally ſpread themſelves over the face of their country, when ſo ſituated; and having only an innocent neighbour or two to converſe with, are ſecured from that corruption which *always attends ſocieties*. This ſeems conſiſtent with an original deſign, and truly worthy of being called the *golden age*. But ſhould a country ſo circumſtanced become too populous,

lous, for its produce; neceſſity would occaſion quarrels, and parties would begin to draw together for mutual defence.---This indeed ſeems to be the natural phyſic which providence has provided againſt the too great population of countries. Whenever a multitude draws together, we never find that multitude without a head. ---This is generally ſome ſpirited and daring villain, to whom the reſt frequently ſubmit, and he in conjunction with others of the ſame genius are ſoon prompted by their ambition to take advantage of *this exigence*, and form themſelves into *governors* and their followers into *ſubjects*. Hence the origine of governments in general, and hence the exigencies that generally give the deſigning *few* the firſt hint of uſurping authority over the *many*. A *government* thus begun, firſt gives credit to, and roots its influence and power, by framing *laws* to rectify ſuch unhappineſſes as the people then labour under from the late quarrels. The *multitude* ſeldom look farther than preſent advantage. Their new governors ſet before them the flattering picture of *order*, *regularity* and *method*. The multitude from their preſent diſtracted ſituation believe any thing right that promiſes them repoſe, naturally fall into the *decoy*, and ſubject themſelves and their poſterity to ſuch rules and oppreſſion as their *maker* never intended. A government thus begun immediately ſets itſelf to work in ſtudying the human mind, its qualities, and tendency; They find the ſoul of man an active principle, full of deſign, forward to execute, and zealous after fame; qualities that are no friends to government;---it therefore becomes the wiſdom of the legiſlature to turn theſe reſtleſs qualities into channels that ſhall not obſtruct the machinery of ſtate,---and hence the riſe of *ſubordination* or *rank* in government,---hence alſo the firſt rude eſſays in *arts*, *ſciences* and *trade*; and hence the firſt longings after ſuperfluous neceſſaries; for the ſleighteſt inſpection into human nature will inform us, that when man becomes *methodized*, he generally becomes *proud* and *ſelfiſh*,---two foundations on which a government may build the moſt *wonderful ſtructures!* Hence *titles* are contrived to reward thoſe aſpiring geniuſes who aſſiſt the new government,---*property* becoming inſured, an eſtate is ſought after by *ſelfiſh adventurers*,---*trade* is the great tub thrown out to employ the multitude, who without buſineſs would, like *Swift's whale* be in danger of overturning the ſhip of ſtate: And thus habits of induſtry are eſtabliſhed,---*all* are employed, and man in taking care for himſelf and a family, forgets the *public*, and *a ſtate of nature*; and a government can purſue its meaſures without obſtruction. But as no authority will be long regarded by the multitude, where the *governors* are not diſtinguiſhed by their manner of living and appearance from the *governed*; and as all diſtinction amongſt the vulgar conſiſts in *ſuperfluous neceſſaries*; hence ariſes at court the neceſſity of *rich cloaths*, *luxurious tables*, *&c.* and that imitating pride natural to the ſoul of man ſoon dictates to the inferior ſort that thoſe *ſuperfluities* are really neceſſary to their happineſs. Thus deluded mortals fall into the traps of ſtate; and hence that eagerneſs in getting money, and ſpending it on things which (having no excellence but in the faſhion of the times, or the whim and caprice of the buyer,) ſoon give way to others equally trifling; the circulation however puts money in the exchequer, keeps the ſlave in dependence, and gives a government the opportunity of eſtabliſhing *manner*, *cuſtom* and *faſhion*---tyrants by which a deſigning ſtate can more effectually rule mankind than by the ſevereſt laws.

Upon a modeſt calculation, the deſtruction of the human race, in building up tyranny by *Seſoſtris*, by *Semiramis*, by *Xerxes*, by *Alexander*, the *Romans*, the *Sicilians*, by *Mithridates*, the *Goths* and *Vandals*, and by the *Spaniards* in the conqueſt of America, *&c.* amounts to forty times the number of mankind now on the face of the earth! In all our experiments we find that *nature* will not ſuffer herſelf to be violated with impunity; her ſtruggles to reſtore the loſt equilebrium of the *air*, of *fire*, *&c.* are not more conſpicuous to the philoſophic eye, than thoſe ſhe makes againſt the fury and madneſs of thoſe curſes of mankind called *conquerors!* Yet has ſhe been drove into the woods and deſarts of the earth, an artificial nature has been ſubſtitued in her place; and miſery and unhappineſs have marked its foot-ſteps,---ſtill does ſhe cry aloud in the human breaſt, but the voice of *prejudice* is louder! ſtill does ſhe whiſper, *The farther you depart from me*, *the more you increaſe your unhappineſs*, but ſhe is not heard!---Forgive, reader, this *honeſt enthuſiaſm*,---TRUTH is the miſtreſs of philoſophy,---and for her ſake we dare run the riſk of that contempt which commonly attends *ſingularity of opinion*.----*Fortification* is the ſubject,---with horror and deteſtation I enter upon it!

When firſt the ambition and addreſs of a *ſingle man* had influence enough to herd his fellow creatures into ſociety, and to inſpire them with the frenzy of his own *wicked views* againſt thoſe who had more ſenſe than be of his party, towns came to be built, and fortified round with a mound of earth for mutual ſafety.---This was a *ſtate*, and others roſe in its neighbourhood, for defence againſt the depredations of the firſt;---thus hoſtility was introduced, and man was taught to think it meritorious to cut the throats of all who were not under the ſame leader.---*Miſchief* being thus eſtabliſhed, fortification became an art of importance; a broad and deep ditch was dug, and on its inner bank huge *walls* were built with round towers at a bow-ſhot diſtance, that overlooked the country, and bid defiance to an enemy's *phalanx* or *battering-ram*. As man became more learned in miſchief, *ſquare towers* with the angle to the field took place of the round ones, and gave the firſt hint of the *bullwark* or *baſtion*; for now one of the *prieſthood* had lent war the aid of chemiſtry and that *diabolical powder*, which has deſtroyed ſo many of the human race, required the united efforts of the *mathematician* and *architect* to evade its power. A *regular fortification* now became ſhaped like an *hexagon*, with a baſtion of well adjuſted angles at each corner, from which an enemy could be *flanked* in what direction ſoever he approached; if he choſe to evade this, and approach the outermoſt angle of the *baſtion* called the *ſalient angle*, his ſhot fell on an *oblique wall* and rolled into the ditch (which ſurrounded the fort) harmleſs: If he choſe to attack the *curtain* (the wall between each baſtion) he had two *baſtions* at leaſt playing upon him, as well as the guns from the *curtain* itſelf, and if he choſe to take the place by a ſudden onſet called a *ſtorm*, a broad and deep ditch, a wall of eight yards high, the cannon and muſketry oppoſed his paſſage; ſo that a fort like this might have been deemed a ſufficient check to military frenzy. But the curtains being found too weak to withſtand the vigorous attacks of an enemy, it was ſoon found neceſſary to cover theſe with extenſive *outworks*, compoſed of angular walls called *ravelins* pointing to the field; and where the country favoured the approach of an enemy, with much ſtronger works, as *crown-works*, *horn-works*, *bonnets*, *&c.* round all which run a large ditch, and the *covert way*, defended by the *glacis* a ſloping bank of earth next the field, and a *paliſado* of ſtrong pieces of wood. Theſe were all ſo adjuſted that two heights of cannon could play over the heads of the muſketry on the covert way; and ſafe communications were cut between each, under the works. If an hill joined the place it had a regular fort built upon it called a *citadel*, which ſerved as a retreat in caſe the town was ſuddenly taken: And forts on the tops of the hills for ſeveral miles round it were deemed neceſſary to retard the approach of an enemy. The art has made no farther advances towards perfection.

When an enemy approaches, they run a ditch with temporary forts round the place called a *line of circumvallation*, this defends them from the ſallies of the *beſieged*, and hinders the eſcape of the town's inhabitants. If an *ally* to the *beſieged* approach, the *beſiegers* run another ditch without the other round themſelves called a *line of contravallation.* The approaches are made towards the town by opening trenches deep enough to defend the men from the town's fire; theſe trenches run in ſuch angular turnings that the *beſieged* cannot fire into them; and when they are got near enough the town a mine is frequently dug that runs under the *baſtion*, from whence it is blown up and the beſiegers ſtorm the place over the ruins, if a capitulation, or a countermine has not taken place before.

LECTURE XII.

OPTICS.

Hail holy light! *Offspring of heaven! Firſt-born!*
Or of th' eternal coeternal beam;
May I expreſs thee *unblam'd?* —— MILTON.

THIS *modeſty* of the *poet* becomes the dignity of ſo divine a ſubject.---*Light* is the bleſſing which gives poignancy to all others,---therefore the ſcience of *optics* which immediately treats of it muſt reflect part of its luſtre and importance. Some believe *light* to exiſt even in the *abſence* of a luminous body, and that it is only the *luminous body* that puts it in motion. The moſt general and probable opinion however is, that it flows immediately *from* the luminous body in ſtreight lines, in all manner of directions, and conſiſts of *particles* ſo infinitely ſmall as to exceed all human comprehenſion.

A proof of this ſmallneſs is, that a *candle* will fill a ſphere of four miles in diameter, without the leaſt ſenſible loſs of its ſubſtance: And if a *row of candles* ſtand parallel to a *black paper* with a *pin-hole* in it, each candle (thro' that hole) will make a ſeparate ſpeck on a *paſteboard* a little behind it. Theſe particles by falling upon the *retina* of our eyes, excite in our minds the idea of light: And when they fall upon bodies, and are by them reflected to our eyes, they excite in us the idea of theſe bodies.

WE cannot ſee thro' the bore of a bended pipe; which proves that light moves in ſtraight lines in *every medium* of *uniform denſity*. But when they paſs *obliquely* out of one medium into another, which is either more *denſe* or more *rare*, they are *refracted* or bent towards the denſer medium, more or leſs as they fall more or leſs obliquely on its ſurface. To prove which put a *ſhilling* in the bottom of an empty veſſel; ſtand ſo far from it that the veſſel may hide the ſhilling; if water be then poured into it the ſhilling will again be ſeen. Hence we are dedeceived in the depth of water: A ſtraight ſtick put in water will appear crooked; and hence the *ſun*'s rays being broken by paſſing thro' our atmoſphere, we ſee him in the *horizon*, before he riſes, and after he ſets in it. When *rays* fall perpendicularly on any medium, they paſs ſtreight thro' without any refraction.

Glaſs is generally ground into eight different ſhapes for optical purpoſes. 1. A *plane-glaſs*, is flat and even on both ſides, and of an uniform thickneſs, will refract the rays of light but not collect them into one focus. 2. A *plano-convex*, is flat on one ſide and convex on the other. When parallel rays fall directly upon it, they paſs thro' it, and are ſo refracted, as to unite in a point called its focus, juſt ſo far behind it, as is equal to the diameter of the ſphere of its convexity. 3. A *double-convex*, is convex on both ſides: Parallel rays paſſing thro'

thro' it *converge* or meet in a focus, at half the diſtance they do thro' the *plano-convex*; and as the heat of all them rays are collected in that focal point, it will burn. 4. A *plano-concave* is flat on one ſide, and concave on the other. 5. The *double-concave*, is concave on both ſides, and parallel rays paſſing thro' both *diverge* or ſpread out agreeable to the laws of refraction. 6. A *meniſcus-glaſs* is convex on one ſide, and concave on the other. 7. A *flat-plano-convex* or multiplying glaſs has its convex ſide ground into ſeveral flat ſurfaces. And 8. the *priſm* has three flat ſides, and viewed endwiſe appears like an equilateral triangle. A ſingle ray falling obliquely upon it in a dark room, will be ſo refracted as to have its parts ſeparated, and ſhew the *ſeven primitive colours* on a white paper, (at correſpondent diſtances to the ſeven notes of muſic) more lively and beautiful than can be equalled by art. If in the rays ſo divided a *double-convex lens* be put, it will bring them into one point that ſhall be perfectly white; which accounts for the *white appearance of the atmoſphere:* As *white* is therefore a compoſition of all colours, ſo *black* is a privation of them all, and properly *no colour*, and muſt exiſt in the ſpace above our atmoſphere: In looking up therefore we ſee what is called the *blue ſky*, a colour naturally reſulting from the mixture of *black* and *white* thro' which we look. All bodies appear of that colour whoſe rays they reflect moſt. As a body is red when it reflects the *red rays*, and abſorbs the reſt. Two or more colours that are quite tranſparent by themſelves, become dark when put together. Thus, if *ſpirit of wine* be tinged *red*, and put in a ſquare bottle, every object ſeen thro' it will be *red*; becauſe it only ſuffers the red rays to paſs thro' it, and ſtops the reſt. If another bottle be tinged blue, all objects viewed thro' it will be blue for the ſame reaſon: But if the two bottles be held together, the object can no more be ſeen thro' them; for whatever rays paſs thro' the bottle next the eye will be ſtopped by the other, &c. Rays of light ſuffer different degrees of refraction, by falling more or leſs obliquely on the *priſm*, a *convex lens*, *&c.* and are thereby ſeparated as above; this happens to them in paſſing thro' *drops of falling rain:* For being *reflected* towards the eye from the ſides of thoſe drops which are fartheſt from the eye, and again *refracted* by paſſing out of theſe drops into the air, they come in refracted directions to the eye, and make all the colours to appear in the form of a fine arch in the heavens, which is called the *rainbow*.

Light is *reflected* by falling on bodies, as a *ball* rebounds when thrown againſt an hard and ſmooth plane: If I ſet up a perpendicular ſtick on that plane, and *throw the ball obliquely at its foot*, it will rebound on the *other* ſide the ſtick, and *form an angle with it*, equal to that in which I threw it, the firſt of theſe is called the *angle of incidence*, and the other the *angle of reflection.* If therefore upon a *plane looking glaſs* a ray falls from any object, if I erect a *perpendicular* there, and go off ſuch a diſtance as to form the *ſame angle* on the other ſide it, I ſhall *ſee the object in a ſtreight line.* Hence I ſee my whole perſon in a glaſs but *half* its length and width; for the rays from my feet ſtriking upon the bottom of the mirrour, will form the *angle of reflection* in my eye the ſame as if it was the *whole* length, *&c.* Hence alſo, the effects of *diagonal mirrours*, *opera glaſſes*, *cameras*, *&c.* Parallel rays falling on a *concave mirrour* will be reflected alſo agreeable to thoſe *angles*, and meet in a point at half the diſtance of the mirrour, from the center of its concavity; if the rays proceed from an hot ſun, his image will likewiſe be found in that point, and burn. The rays which proceed from any *terreſtrial object*, come *diverging* to the mirrour, and therefore will not be *converged to a point* at half the diſtance of the mirrour's ſurface from the center of its concavity, but *nearer to that ſurface*; the image will be leſs than the *object*, but will be ſeen *inverted*, and hanging pendant in the air quite diſtinct by an eye placed oppoſite the mirrour. If the *object* be *in* the *center of the mirrours concavity*, the *image* and *object* will be *together* and of *equal bulk:* Therefore when the object is more remote than the center of concavity, the *image* will be *leſs* than the *object*, and between the *object* and *mirrour:* But when the object is *nearer* than the center of concavity, the *image* will be *more remote*, and *bigger* than the object. The angles of *incidence* and *reflection*, alſo accounts for the *ſmall image* in a *convex mirrour*.

THE *human eye* is lodged in a bed of fat, and ſecured in an hollow orb of bone,---'tis moved by *muſcles* which act on its outſide like *pullies*; and conſiſts of *four coats*, and *three humours*. The coat in which the *back part* of the eye is contained is called the *ſclerotica*; it is a *large portion of a globe*, very ſtrong and of a non-elaſtic nature, ---that part which *completes the globe* on the *fore part* of the eye, is the *cornea*; it bulges a little forward out of that ſhape, and is a fine tranſparent membrane. Next within this coat is that called the *choroides*, which ſerves as it were for a *ſoft lining* for the other; and within this is ſpread a fine expanſion of the optic nerve like a net, called the *retina*, upon which are painted as in a *camera obſcura* the images of all viſible objects, by the rays of light that flow from them: The *iris* is compoſed of two ſets of muſcular fibres, which dilate or contract the *hole* in it called the *pupil*, ſo as to adapt it to a ſtrong or weak light. The *adnata* or *conjunctiva* is the white of the eye, a fine membrane that *folds under the eye-lid*, and joins to it. Under the *cornea* is a fine tranſparent fluid like water, and thence called the *aqueous humour:* It gives the protuberant figure to the cornea, and goes thro' the pupil. Behind this lies the *cryſtalline humour*, ſhaped like a double convex glaſs, tranſparent as cryſtal, of the conſiſtence of hard jelly, and which converges the rays that paſs thro' it to a focus on the *retina*. It is incloſed in a fine tranſparent membrane, from which proceed radical fibres called the *ligamentum ciliare*, all round its edge, and join to the out edge of the *iris:* Theſe fibres by a power of contracting and dilating alter the convexity of the *cryſtalline humour* and ſhift it a little *backward* or *forward* in the eye to ſuit it to the different diſtances of objects (*an admirable proviſion!*) The *cryſtalline humour* is bedded on the *vitreous humour*, which fills the whole orb of the eye, and is tranſparent like glaſs; the largeſt of all in quantity, and is much of a conſiſtence with the white of an egg. The *optic nerve* comes from the *brain*, thro' the *ſclerotica* and *choroides*, on that ſide the eye next the noſe; and is incloſed on the outſide the eye by coats proceeding from the *pia* and *dura mater*, and of which the *ſclerotica* and *choroides* are but a continuation. Theſe are the parts of this wonderful organ.

Rays from any *object* ſtream upon the *retina*, and there paint it invertedly, as may be ſeen by cutting off the three coats from the back part of a freſh bullock's eye, and putting a piece of white paper over that part: If the eye is then held before any bright object, an inverted picture of it will be painted on the paper. The *optic nerve* incloſes a *blood veſſel*, which renders objects inviſible that fall on it; how wiſely therefore is it placed on one ſide of each eye! that the ſame parts of an image which fall on the optic nerve of *one* eye ſhould not fall on the *other!* If three patches are placed at a foot diſtance from each other on a wall, if the *right* eye be covered, and the *left* look ſtedfaſtly at the right hand patch, that on the left hand will diſappear, becauſe it falls on the artery in the optic nerve.

The nearer that any object is to the eye, the larger is the angle under which it is ſeen; therefore a tall object looks twice larger at *one* than at *two* miles diſtance. Hence the uſe of *convex glaſſes*, which by increaſing *this* angle, makes *minute objects* viſible; and when the

humours

humours are grown ſo flat in decayed eyes, that the picture falls behind the retina, can bring the rays to converge ſo that the picture ſhall be brought back to the *retina.* Hence alſo the reaſon that the *too round* eye requires the *double-concave* glaſs by its divergency to remove the image from the vitreous humour forward to the retina.

The *ſingle microſcope*, is only a ſmall convex glaſs, having the object placed in its focus, and the eye at the ſame diſtance on the other ſide. Its magnifying power is thus calculated. A good eye cannot ſee any object diſtinctly at leſs than ſix inches diſtance; if this be divided by the focal diſtance of the glaſs, the quotient will be how much the diameter of the object is multiplied.

The *double microſcope*, conſiſts of an *object glaſs*, and an *eye glaſs*, between which the image is formed, and magnified, by having the object a little further from the object glaſs than its principal focus; this image brought ſo near is viewed by the eye thro' the eye glaſs. If each glaſs magnifies *ſix times*, (as by the laſt calculation) then is the object magnified *thirty ſix times* by both. This inſtrument is equipt with a mirrour which by the *angle of incidence* and *reflection* throws up light on the *underſide* the object; which object being placed in the focus of a *moveable lens*, has its *upperſide* enlightened alſo.

The *ſolar microſcope* is placed in a round hole in a ſhutter that only admits into a dark room, a ſmall cylinder of rays; that theſe rays may be ſent ſtraight thro' the tube, a plain mirrour on the *outſide* is ſo fixed as to reflect them in; they then paſs thro' a large convex lens; after which, they fall upon, and enlighten the object, which is placed in the focus of a *ſmall magnifier*, thro' which they carry a large inverted image of the object to a white ſheet placed at any diſtance for its reception.

A *refracting teleſcope*, may be made of *two convex glaſſes viz.* an *object glaſs* and an *eye glaſs*, if the focus of the *eye glaſs* be in the ſame part of the tube where the image is formed by the *object glaſs*; but then the image will be inverted, and therefore 'tis only ſuitable for celeſtial objects The magnifying power of this teleſcope is as the focal diſtance of the *object glaſs*, to the focal diſtance of the *eye glaſs*: therefore if the *former* be divided by the *latter*, the quotient will expreſs the magnifying power; and ſhew, that if the focal diſtance of *each were alike*, the magnifying power of the teleſcope would be nothing; and that this magnifying power will increaſe with its length, for the greater the focal diſtance of the object glaſs, the leſs may be the focus of the eye glaſs.

A *refracting teleſcope*, that will ſhew objects in their natural poſture, muſt have *two equal convex glaſſes* added to the eye glaſs, and all three muſt ſtand at double their focal diſtances from one another. As theſe three do but as it were compoſe one eye glaſs, the magnifying power of this teleſcope may be calculated as the laſt.

Doland's patent teleſcope is formed on the ſame principles only its object glaſs is much larger, and is compoſed of two joining glaſſes of different denſities, one a *plano-concave*, and the other a *double convex* that fits into the others concavity. Theſe makes the field of view larger, and by taking off the coloured rays, the image becomes bright and quite diſtinct: For as the rays which paſs thro' the edge of a *convex glaſs* are more *unequally refracted* than thoſe which paſs nearer its *middle*, they don't meet in the ſame point, but form a circle of priſmatic colours round the image: In the *common teleſcope*

ſcope theſe are partly taken off by a *black plate* fixed in the tube, with an hole thro' its center; but the *patent glaſs* does this much more effectually.

The *reflecting teleſcope* exceeds all others in its *magnifying power* and *portable ſize*; and its outward figure conſiſts of a great and ſmall tube, ſcrewed to the end of one another. At the bottom of the great tube is placed the large concave mirrour with an hole thro' its middle. Parallel rays from a celeſtial object falling on this mirrour, are reflected back by it, and form the *image* a little ſhort of the *ſmall concave mirrour* which faces the hole in the large one. From this image the rays diverge to the ſmall mirrour, and are from thence reflected parallel and inverted into the ſmall tube, thro' the hole in the large mirrour; here meeting with a convex lens, they are ſo refracted as to form the image in the *ſmall tube*. The *image being now brought ſo near*, requires nothing but a ſingle or compound *eye glaſs* to ſend it duly magnified to the retina. Rays from any terreſtrial object *will not come parallel* but diverge a little; hence the image is formed further from the great mirrour, and therefore a ſcrew is fixed to the ſmall mirrour on the outſide the tube to adjuſt it to it; and alſo to the *greater or leſs convexity* of different eyes.

The *diagonal mirrour*, for viewing prints, is a pleaſing inſtrument. If a *plane mirrour* be placed at an angle of 45 degrees above a print lying horizontal and inverted, it will turn the rays reflected from the print into an horizontal direction to the eye: If then a *large convex lens* be placed between the eye and the mirrour, the picture will be prodigiouſly magnified; and if an aſſemblage of *ſhell work* environ the view between the *print and the mirrour*, the picture will have a beautiful frame to it.

The *camera obſcura* is formed on the ſame principles.

A

A *diagonal mirrour* is ſet at the ſame angle againſt the landſcape, and reflects it downwards thro' a *convex lens* into a *dark box*, where it is painted on a *white paper* placed in the focus of the lens, and on which a hand put into the box may draw the landſcape to the minuteſt exactneſs.

The *opera glaſs*, is alſo formed of a ſmall diagonal mirrour which ſends the rays thro' a convex glaſs to the eye. Thro' this a gentleman may look at a diſtant lady in the company, and the lady know nothing of it.

The *magic lanthorn*, is formed on the ſame principles as the *ſolar microſcope*; a candle ſupplies the place of the ſun; and having its rays tinged with the colours of *tranſparent figures painted on glaſs* throws them thro' two convex lenſes on a white wall in a dark room, prodigiouſly magnified.

FINIS,

EXPLANATION

Of ſuch uncommon Words, as could not, without affectation, be omitted in this COURSE.

A

ABSORB, *to drink in.*
Acid, *ſour.*
Accelerated, *haſtened, hurried forward.*
Accumulate, *to heap up.*
Adheſion, *the ſticking together.*
Alkali, *fixed ſalt of ſubſtances fermenting with acids.*
Analogy, *likeneſs, proportion.*
Apparatus, *inſtruments for experiments.*
Attraction, *a drawing together.*
Axis, *an axle on which any thing turns.*

C

Capillary, *ſmall as an hair.*
Centrifugal, *a direction given to a body different from that inclining to the center.*
Centripetal, *tending towards the center.*
Coheſion, *clinging, or ſticking together.*
Collateral, *lying ſide by ſide.*
Compreſs, *to ſqueeze together.*
Concave, *ſpherically hollow.*
Condenſe, *to bring the parts of matter cloſe together.*
Contact, *touching each other.*
Convex, *ſwelling ſpherically outwards.*
Converge, *to draw towards a point.*
Cylinder, *like a rolling ſtone.*

D

Diverge, *to ſpread out.*
Denſity, *compactneſs, cloſeneſs.*
Diagonal, *the line running between oppoſite corners of a ſquare.*

E

Ebulition, *a bubbling like boiling water.*
Elaſtic, *having a ſpring.*
Effervеſcence, *a waxing hot.*
Ellipſis, *an oval line or ſurface.*

F

Fibre, *a ſmall ſtring.*
Flaccid, *lax, looſe, or flabby.*
Fulcrum, *a prop or point of ſupport.*
Frigorific, *chill, or cauſing cold.*

G

Gravity, *weight or the tendency one body has to another.*

H

Hemiſphere, *half a globe.*
Hermetically ſealed, *tube cloſed with melted glaſs.*
Hypotheſis, *a ſuppoſition.*

I

Immerſe, *to dip or plunge in.*
Impel, *to drive onwards.*
Incompreſſible, *not to be ſqueezed into leſs compaſs.*
Incidence, *a falling or lighting on.*
Interſtices, *intervals, or intermediate ſpaces.*

L

Lateral, *ſidewiſe.*
Longitudinal, *lengthwiſe.*

M

Meatus auditorius, *the paſſage into the ear.*
Medium, *a means of conveyance*
Membrani timpani, *the drum of the ear.*
Momentum, *the force of a body.*

O

Oblique, *crooked, inclining,*
Orbit, *the track deſcribed by a planet round the ſun*

P

Particles, *exceeding ſmall parts.*
Percuſſion, *ſtriking, or the effects of a ſtroke.*
Perforate, *to bore thro'.*
Phenomenon, *an appearance in nature.*
Piſton, *a moveable plug, juſt fitting a pipe.*
Pores, *ſmall interſtices in bodies.*
Preponderate, *to deſcend, be heavier.*
Projectile, *a body in motion, caſt or thrown.*

R

Rarefy, *to thin, to make denſe matter weaker,*
Reflection, *rebounding back, returning.*
Reciprocal, *mutual, relative.*
Refract, *to incline, or break.*
Reſervoir, *a ciſtern or head for a reſerve [illegible] water.*
Reverberate, *to beat back, to eccho.*
Rotation, *a turning about.*

S

Saturation, *abſorption, drinking in, &c.*
Secrete, *to ſeparate.*
Senſorium, *the ſeat of perception in the brain.*
Species, *ſort or kind.*
Specific, *peculiar, bulk for bulk.*
Spiral, *like a rope coiled round.*
Subterraneous, *within the earth.*
Syphon, *a bent tube, or crane.*
Syſtem, *compoſition, a general ſtructure.*

T

Tangent, *a ſtraight line touching the circumference of a circle.*
Tenacity, *a clinging together.*
Tenſion, *a ſtretching out.*
Tranſit, *the paſſing of a planet before the face of another, or the ſun.*
Tube, *a pipe.*

V

Valve, *a trap door, letting a fluid come thro' but not return.*
Velocity, *the moving ſpeed.*
Vertex, *the point on the top of any thing.*
Vibrate, *to ſwing as a pendulum.*
Undulating, *moving in waves.*
Volatile, *ſubject to evaporate or fly off.*

Z

Zone, *a belt.*

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